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ABSTRACT

The Developmental Approaches in Science, Health and Technology (DASH) program provides opportunities for students to experience the worlds of scientists and technologists in elementary classrooms. It aims to build an understanding of technology and science through constructivism and hands-on science for K-6 graders. This instructional guide introduces the DASH program and presents its instructional strategies. Contents include: (1) Introduction; (2) DASH Instructional Strategies; (3) Grouping; (4) Inquiry Model; (5) Questioning; (6) Integration; (7) Technology; (8) Assessment; (9) Support; and (10) Addendum. (Author/YDS)

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Developmental Approaches in Science, Health and Technology

Instructional Guide

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CRDG Curriculum Research & Development Group

SE 067 536

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Instructional Guide 2000
Developmental Approaches in Science, Health and Technology

Some of the materials in this program are based on activities from the Hawai'i Nutrition Education and the Science Curriculum Integration Project of the Hawai'i Department of Education.

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Developmental Approaches in Science, Health and Technology (DASH)

A Program for Kindergarten through Grade 6

The *Developmental Approaches in Science, Health and Technology (DASH)* program brings the working worlds of technologists and scientists into elementary classrooms. By doing the sorts of things that occupy naturalists, biologists, astronomers, meteorologists, physicists, chemists, ecologists, farmers, engineers, nutritionists, and health service providers, *DASH* students build understanding of technology and science.

DASH materials offer over 650 interconnected hands-on activities for grades K-6 that progressively support students' construction of the basic concepts and skills on which our technoscientific society relies. *DASH* students become aware of the social impact of science and technology in and out of school, and they work to enhance the quality of their environment by conserving and recycling materials and attending to ways of reducing pollution. They enter middle school or junior high ready for laboratory and field science and armed with knowledge of their own biology and the destructive effects of drugs and disease.

DASH is a user-friendly program that furnishes professional support for teachers to use it effectively.

DASH is a product of the Curriculum Research & Development Group (CRDG), at the University of Hawai'i. Funding for developing the program has come from the University of Hawai'i; the National Science Foundation; the Hawai'i Department of Business, Economic Development, and Tourism; and the Buhl Science Foundation. The CRDG sustains continuing research and development.

Features of *DASH*

By designing and field-testing activities for diverse school settings, *DASH* solves a range of problems inherent in traditional teacher-centered and textbook-delivered elementary science programs. In *DASH,* students learn content and skills through engaging activities that use kinesthetic and visual modes of learning along with linguistic and mathematical modes. Working as a cooperative community of researchers, they construct generalizations and explanations out of common observations and experiments that focus on the world in which they live rather than on the abstracted world of the textbook. Standard field guides, references, and newspapers are resources that make reading a helpful tool rather than the primary vehicle of instruction.

By integrating the content of science and health and incorporating the study of technology, *DASH* achieves economy in the use of instructional time. Furthermore, such topics as nutrition, damaging substances, and sexually transmitted diseases fit into the logic of the activity sequences so that they need no extra time.

DASH addresses the standards for science education set by the National Research Council (NRC), the American Association for the Advancement of Science (AAAS), and the National Center for Improvement of Science Education (NCISE).

DASH is grounded in constructivist philosophy

DASH embraces the constructivist idea that learning is a personal process of constructing meaning from evidence. Out of their life experiences, students build their own unique understandings of the world, which over time are shaped to conform to the to the collective understandings of society. This normalizing process comes about through human interaction, particularly in the school. In this view, teaching is creating contexts that motivate learners to devise their own constructs and that allow for intellectual and societal normalization.

DASH presents a sequence of developmentally appropriate contexts rich in links to earlier experience in and out of school and filled with opportunities for normalization. *DASH* students spend 75 to 80 percent of their time working with tools and materials and trying to make sense of natural phenomena. The rest of their time goes into interactive reflecting, recording, and reporting.

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DASH content recapitulates the history of science

Constructivists note that children build their understanding of science as they recapitulate, or relive, its history, spontaneously solving problems without evident reflection. They build the same intuitive notions about the earth, sky, animals, plants, and the workings of mechanical things that early Greeks and Romans reported. Not until they live through this period of intuition can they enter the logical and often counterintuitive world of modern science. In *DASH*, students begin experimental science only as their linguistic and logical faculties mature.

DASH students are first of all technologists, doers and makers, natural scientists, observers and describers. In the upper elementary grades they become producers and users of explanations from ecology, biology, rudimentary chemistry, earth science, and physics. They use the processes and intellectual tools of technologists, who invent, design, construct, and test solutions to mechanical, environmental and health problems, and of scientists, who observe, generalize, hypothesize, design, experiment, and interpret data to explain phenomena.

DASH is comprehensive

The *DASH* program for grades K-6 comprises science, health, and technology. Students first study the basic biological needs of living things and the technologies humans use to satisfy those needs. They learn of the need for food, water, air, bodily protection, sanitation, mobility, and communication; they work at the tasks of engineering, farming, producing materials, constructing things, preparing and marketing food, processing information, and a host of other tasks. Technology studies mesh with the science and health components, giving students practical experiences in basing their solutions to problems on understanding of natural phenomena.

Science studies in grades K–3 engage students in observing, categorizing, and generalizing about the natural world—weather, plants, animals, and astronomy. Beginning in grade 4, they meet anomalies that stimulate them to experiment, creating research designs and testing their own hypotheses. They explore basic biological, chemical, and physical phenomena as these apply to technological and health studies.

In health studies *DASH* students become nutritionists, safety engineers, health service workers, and veterinarians. Health study begins with topics immediately important to students—disease transmission, sanitation, nutrition, safety, and personal physiology. Study in the upper elementary grades expands into human reproduction and the perils of drugs, tobacco, alcohol, and sexually transmitted diseases. A mental health component running through the whole program is keyed to students' intellectual growth, social interaction, and responsibility.

Throughout *DASH* students are urged to reflect on how the interests of science, technology, and society most often coincide but sometimes conflict and what they as citizens might do when conflict arises.

DASH uses multigrade developmental sequences

Concepts and skills typical of different technologies and sciences unfold year by year as students become ready to understand them. One example is the *DASH* astronomy sequence.

Kindergarten. Students begin by observing the sun, moon, and stars. They discover that the moon goes through a regular sequence of phases about every 28 days; that in all but the most northern regions, the sun and stars rise in the east and set in the west; and that the moon rises and sets like the sun.

Grade 1. Students begin to record the rising and the setting times of the sun. They use digital time, graph the length of day and night, and relate their graphs to the seasons.

Grade 2. Students identify solstices and equinoxes and connect these to the seasons. They use analog time, graph the rising and setting of the moon, and build a camera obscura to observe the sun.

Grade 3. Students continue the study of day and night in relation to seasons and make a polar star planetarium to explore the night sky and the movement of Venus.

Grade 4. Students make gnomons to follow the apparent north–south journey of the sun and correlate this movement with seasons. They make sun dials to study local time; they make northern hemisphere planetariums to study the major constellation of the zodiac and the planets.

Grade 5. Students continue collecting gnomon data to understand the ecliptic and build telescopes to observe the changing face of the moon. They calculate distances to the moon and sun and use this knowledge, along with their planetariums, to test the logic of Ptolemaic and Copernican models of the solar system.

Grade 6. Students crown their astronomy studies in a detailed investigation of Mars, focusing on whether human occupation of the planet is possible—a reflective study calling on all their understanding of planet Earth as they look at our neighbor in space. Using their knowledge of the solar system and the stars, they plan an interplanetary flight. Drawing on their knowledge of survival conditions on Earth, they create a habitat to withstand the inhospitable conditions of the red planet and simulate a day of living on its surface.

DASH balances process and content

DASH activities balance content and process. By stressing both knowledge and the processes by which it is generated, *DASH* enables students to deepen their understanding of how scientists and technologists work. Students then use new knowledge and skills regularly, both to reinforce them and to link them to other subjects and to the world about them.

DASH fosters collaborative learning

DASH draws on collaborative communities of scientific and industrial researchers as its model for classroom dynamics. Studies by advocates of cooperative learning have corroborated the educational value of such models and have suggested further techniques for *DASH* class operation.

DASH is designed for heterogeneous groups

In line with the collaborative model, *DASH* activities have been designed for use in heterogeneous classes in the regular school program. Technology and science have been built by people of vastly diverse talents; thus a class that reflects the experience of science and technology must also call on a spectrum of talents. We as teachers have only a marginal capacity to detect students' latent talents and inclinations; a heterogeneous mix allows students' unnoticed abilities and interests to evolve and mature. Heterogeneous classes build an egalitarian sense of social responsibility and good citizenship and assure quality in science education for all.

DASH integrates with other subjects

DASH presents contexts that draw on and add to the knowledge and skills that students learn in other school subjects. *DASH* uses measurement, calculation, and geometric analysis, which naturally reinforce mathematics. *DASH* builds on the social nature of learning, identifies career roles in each activity, and presents geographic and ecological concepts, all of which support social studies. *DASH* requires inventing, constructing, drawing, and making models of devices, thereby amplifying the graphic and fabricating arts. Every *DASH* activity is an integrated language experience that entails keeping records of ongoing and completed work; using resource books, newspapers, and periodicals; and hearing and speaking the language of social and scientific interaction.

DASH integrates assessment with instruction

Assessment in *DASH* is an integral and essential part of instruction, shared by teacher and students and essential to both parties in planning. A *DASH* teacher engages students in solving problems, responds with feedback, and adjusts the instruction in line with students' responses. Assessment is usually informal, immediate, and multidimensional. Most important is students' development of a self-assessing capacity. To fill in knowledge gaps not detectable by the teacher, they must think about what they know and don't know. Every act of assessment becomes a learning and objective-setting experience for the student. To provide a picture of personal learning, *DASH* students keep a portfolio of products that tell the story of their intellectual progress.

DASH students create an array of products for assessment

In *DASH* activities students generate products, many of which are devices or pieces of equipment they use in later inquiries or classroom functions. Others are records of work done. All are part of a student's assessment portfolio. Students soon grasp that the sciences and technologies are product-oriented—that science produces descriptions and explanations, and technology produces goods and services.

DASH uses recycled materials

DASH does not require kits of science materials. Instead, *DASH* has devised equipment that students can make from throwaway items and materials commonly available in home and classroom. From making their own gear, students learn more than they do from assembling prefabricated parts. Furthermore, they can replicate or extend a class activity at home. Making their own also reinforces the idea of recycling materials, and it reduces the costs of science instruction. With "kit science," students get the feeling that studying science and technology can be done only at school under the supervision of an adult.

DASH includes a family component

DASH stresses connecting its activities to experiences at home and elsewhere. Some in-class projects call for further exploration at home. *DASH* colleagues at Carnegie Mellon University have written a set of newsletters called *DASH on Home* to communicate with families about what is happening in school. These newsletters explain *DASH* investigations and suggest ways to reinforce and extend in-school learning at home. The letters reserve space for teachers to add their own messages.

DASH supplies an administrator component

Because administrators are crucial to success in implementing new educational programs, *DASH* uses several means to inform and support administrators, including workshops, consultations, and a handbook for administrators.

The *DASH* Handbook for Administrators carries information on the kinds of support needed for implementing *DASH*. The handbook discusses supplies, local purchase items, written materials, staff development, and ways to determine where teachers are in their implementation. It includes information for parents and boards of education about the theoretical base of *DASH*, its goals and objectives, pedagogy, and ways to evaluate it.

DASH meets national standards

DASH meets each of the standards set by the National Center for Improving Science Education (NCISE).

- √ Accessible to all students.
- √ Builds on student's prior experience and knowledge.
- √ Uses an instructional model based on scientific processes such as questioning, discovering, creating, communicating, and pursuing new questions.
- √ Relates to personal and social needs.
- √ Selects science concepts that are developmentally appropriate, with examples drawn from the content of multiple disciplines of science.
- √ Develops scientific thinking skills such as drawing conclusions from evidence, using inference, and creating models.
- √ Develops scientific habits of mind such as curiosity, skepticism, honesty, and living with ambiguity.
- √ Uses authentic assessments to chart teaching and learning.
- √ Shifts the role of teacher from imparter of knowledge to designer and facilitator of learning.
- √ Seeks to find relevant and significant applications of science content and concepts to students' personal and community life.

DASH also addresses the Benchmarks for Scientific Literacy published by the American Association for the Advancement of Science (AAAS) and the standards released by the National Research Council (NRC).

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THE STANDARDS-BASED MOVEMENT: WHERE DO WE STAND?

I challenge every community, school, and state to adopt national standards of excellence, measure whether schools are meeting those standards, cut red tape so that schools have more flexibility for grassroots reforms, and hold them accountable for results by embracing our Goals 2000 initiative.

President Bill Clinton
State of the Union address, January 1996

This is an exciting time in science education—in the United States and elsewhere. In the US, we are in the midst of a major reform movement that has been stimulated by a sense of impending danger of being eclipsed economically and technologically by other countries—particularly Japan and Germany.

The last time there was such a national concern was after the first Russian sputnik was launched in 1957. Then, we were shocked that Russia might be more technologically advanced than the United States. We initiated multi-million dollar projects in education to produce more scientists and engineers. Now, as then, science literacy is seen as closely connected to economic and technological development and progress.

But the current reform is affecting more than just science and mathematics education. Professional organizations devoted to every subject from mathematics to physical education are working intently to define standards. The National Council of Teachers of Mathematics led the way when it released mathematics standards in 1989. Standards in the arts followed in March 1994, and standards in geography were released in October. Standards for science have been drafted by several professional organizations including the National Center for Improving Science Education (NCISE), the American Association for the Advancement of Science (AAAS), the National Science Teachers Association (NSTA), and the National Research Council (NRC), but none have officially been adopted at the national level.

WHAT ARE STANDARDS?

A standard is a statement that can be used to judge quality. Content standards are statements of what all students should know, be able to do, and care about as a result of their science education. They are goals for students and teachers to strive for.

Teaching standards are statements of what effective teachers do in classrooms that enable students to achieve high content standards. Professional development standards describe what is known about highly effective professional development activities.

FEDERAL vs STATES RIGHTS

In the United States, education is a State right. This is guaranteed by the United States Constitution. It is not a federal responsibility. So, this reform movement is both historically significant and controversial. It is the first time in the history of our country that there has been a call for a unified, national approach to education. And, there is great fear that establishing a set of national standards will result in a national curriculum and threaten local control of education. Interestingly, President Clinton in his State of the Union address continues to call for national standards and grassroots reforms, an approach that can be viewed as paradoxical and contradictory.

It will be up to each state to accept, adapt, and localize the new standards and to improve their educational systems to achieve the new goals. This is being done state-by-state by developing State Science Frameworks. Frameworks describe each state's plans, requirements, and curriculum sequence for achieving a standards-based education for all its citizens. Figure 1 shows the relationships of science frameworks and national standards in efforts to improve science education.

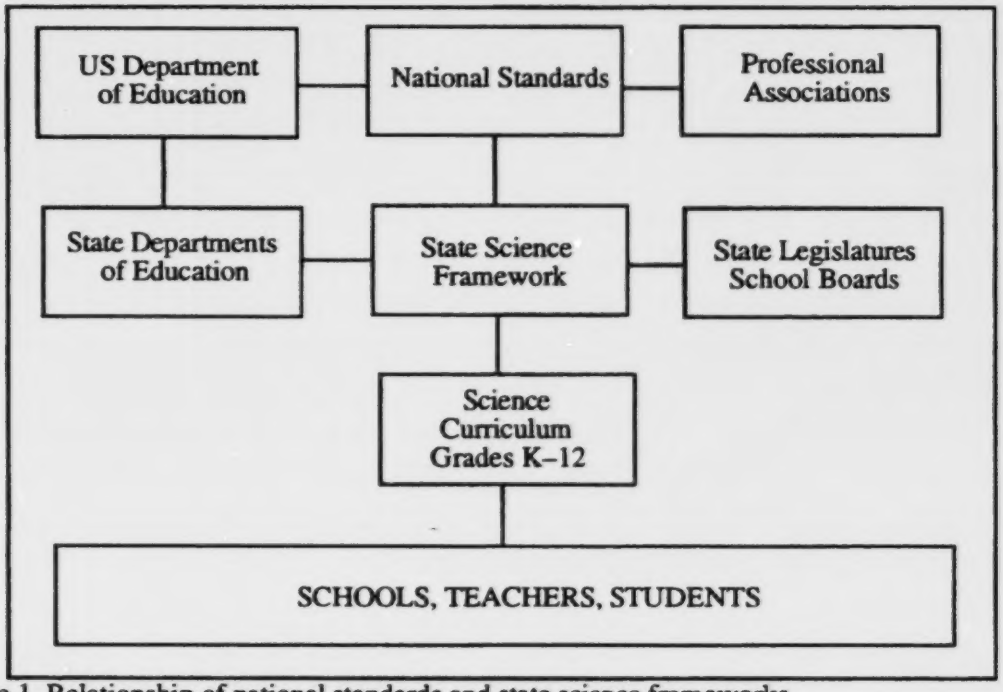

Figure 1. Relationship of national standards and state science frameworks

EDUCATE AMERICA 2000

The Educate America 2000 Act which passed Congress in March 1994 establishes eight national goals for education, national standards in all subject areas, and provides for national assessments. Its themes are change, opportunity for all, responsibility placed on schools to improve literacy, and the national economy tied to educational improvement.

The act codified into law eight national goals:

1. All students will start school ready to learn
2. High school graduation rate of at least 90%
3. Students will leave school having competency in challenging subject matter (English, history, mathematics science, geography) prepared to use their minds well for
   - responsible citizenship
   - further learning
   - productive employment
4. The United States will be first in the world in science and math achievement by 2000
5. All adults will be literate and able to compete in a global economy
6. Schools will be conducive to learning and free of drugs and violence
7. Parents will be active participants in their children's' education
8. Career-long professional development of teachers.

This new law establishes the National Education Goals Panel to report annually on state and national progress in achieving the eight goals. It also establishes the National Education Standards and Improvement Council (NESIC) to certify state-developed standards for content, opportunity to learn, and assessment. Each state is required to develop a comprehensive improvement plan that must address school-based opportunity to learn, management and governance of schools, parent and community involvement, systemic reform, and funding to districts, schools, and higher education.

NATIONAL SCIENCE STANDARDS

It is within the Educate America 2000 Act that the standards-based reform movement is lodged. For the first time in the United States there is an acknowledgment that we need rigorous standards in science education that set high expectations for curriculum, teaching, and assessment.

As stated earlier, there are several major efforts underway to establish standards for science teaching and learning. One of the earliest efforts was that of the National Center for Improving Science Education in Washington, DC. They developed and published standards for science education based on research findings and recommendations of leading science educators. These were the standards that the U.S. Department of Education used in identifying and selecting programs to include in their publication *Promising Practices in Mathematics and Science Education* (1994). CRDG's DASH, FAST, HMSS and Algebra projects are all included as programs that meet the new standards.

American Association for the Advancement of Science (AAAS)

The American Association for the Advancement of Science (AAAS) in their publication *Project 2061 Science for all Americans* (1989) took a leadership role in redefining scientific literacy, emphasizing what all students should know and understand about science, and recommending teaching in ways that address all students' learning styles, abilities, and cultural backgrounds.

More recently AAAS published standards for specific grade levels with rich descriptions of learning environments. Published in 1993, *Benchmarks for Science Literacy*, emphasizes that all teachers have responsibility for teaching science from grades K–12. Benchmark is the term AAAS uses instead of standard.

Benchmarks includes 852 standards organized into 12 chapters describing what students should know and be able to do by the end of grades 2, 5, 8, and 12. *Benchmarks* is designed as a companion to *Science for All Americans.* Chapters in *Benchmarks* correspond to the chapters in *Science for All Americans. Benchmarks* maps out the significant knowledge and skills that students will have to develop as they progress through school to become scientifically literate citizens. The intent is to specify thresholds rather than average or advanced performance. It is not a curriculum; it is a tool for schools to use in planning, developing, organizing, and delivering an instructional program. AAAS expects that there are diverse pathways to achieving science literacy.

National Research Council (NRC)

Another professional association involved in the development of standards is the National Academy of Sciences through its National Research Council (NRC). The NRC organized in 1916, has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities.

In the spring of 1991, the National Science Teachers Association president, with support from other professional associations, the U.S. Secretary of Education, and others, encouraged the NRC to coordinate development of national science education standards. Shortly thereafter, major funding for NRC to develop national standards in science was provided by the U.S. Department of

Education and the National Science Foundation. Thus, the NRC is the group officially responsible for setting national standards in science education that reflect Educate America 2000 Goals (NRC 1996).

Following extensive national review, the final document was printed in December 1995. Unlike *Benchmarks*, the NRC document includes six sets of standards: teaching; professional development; assessment; content; programs; and systems. The major topics included in each set are shown in Table 5. As with *Benchmarks*, there is significant emphasis throughout the standards on humanizing science education. Note, for example, the inclusion of personal and social perspectives of science in the content standards, the emphasis on providing equal opportunity for all students to learn science in the program standards, the matching of assessment to opportunity for students to learn in the assessment standards, and the focus on student learning and lifelong learning in the professional development standards.

Benchmarks and Content Standards Compared

The AAAS *Benchmarks* and NRC *Standards* share a common emphasis on the content that all students should know, the recognition that such understanding can only be developed over a long developmental period from grades K through 12, the responsibility of teachers at all grade levels to help students develop understanding, and that understanding requires mastery of a large number of related concepts. Table 2 provides a comparison of the two documents.

There appears to be about an 80% overlap between the two documents in specifying what all students should know and be able to do as a result of their science education. Though *Benchmarks* is more comprehensive in specifying science content and related areas of mathematics, technology, and social issues, *Standards* goes beyond content to provide standards for supporting the reform effort at the teaching, assessment, professional development, program, and system levels. Clearly, effective change will not occur without the commitment and support of the entire educational community.

Table 2. Comparison of AAAS benchmarks and the NRC content standards

Comparison	AAAS Benchmarks	NRC Standards
Stated Goals	Scientific literacy means • being familiar with the natural world, its diversity and unity • understanding key concepts and principles of science • being aware of the interdependence of science, math, and technology • knowing that all three are human enterprises and have weaknesses • having a capacity for scientific ways of thinking • using scientific knowledge and ways of thinking for social purposes	The goals for school science are to educate students who are able to • experience the richness and excitement of knowing about and understanding the natural world • use appropriate scientific processes and principles in making personal decisions • engage intelligently in public discourse and debate about matters of scientific and technological concern • increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers.
Format	Chapter Connection to *Science for All Americans* Comments on student learning Section Introduction Research finding Related benchmarks Grade-level benchmarks	Standard Developing student understanding Guide to the content standard Fundamental concepts and principles
Organization	Twelve Chapters Sections within chapters Benchmarks identified under sections The Nature of Science The Nature of Mathematics The Nature of Technology The Physical Setting The Living Environment The Human Organism Human Society The Designed World The Mathematical World Historical Perspectives Common Themes Habits of Mind	Eight Content Standards Related fundamental concepts and principles associated with each standard Unifying Concepts and Processes in Science Science as Inquiry Physical Science Life Science Earth and Space Science Science and Technology Science in Personal and Social Perspectives History and Nature of Science
Grade Clusters	Grades: K–2; 3–5; 6–8; 9–12	Grades: K–4; 5–8; 9–12
Additional Support	*Project 2061: Science for All Americans* defines scientific literacy and a rationale for including all students. Benchmarks • Chapter 13 Origin of the Benchmarks • Chapter 14 Issues and Language • Chapter 15 The Research Base	Additional standards for • Teaching (6 standards) • Professional Development (4 standards) • Assessment (5 standards) • Science Program (6 standards) • Educational System (7 standards)

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New Visions for Science Education

While there is by no means consensus among the approaches, review of the science reform efforts reveals striking similarities that point the way to a major shift in how science is to be taught and learned. A summary of these changes is shown in Table 3.

Table 3. Summary of science education reform movement

TRADITIONAL APPROACH	REFORM APPROACH
Science for some	Science for all
Reading/language first	Inquiry and activity-based instruction that integrates language development
Teacher as an imparter of knowledge	Teacher as a facilitator of learning
Content driven	Constructivist approach in which learning builds on prior knowledge
Divorced from real world	Science applied to students' lives; relates to personal & social needs
Individual	Collaborative/social
Atomistic/disconnected	Holistic/connected; thematic with facts integrated
Single exposure	Spiral curriculum; sequential
Memorization	New modes of inquiry emphasizing thinking skills and scientific habits of mind
Testing	Multidimensional assessment to chart learning and teaching

Why Is Science Education So Important For All Students?

A major shift in this reform effort is an attempt to educate all students to a high level of scientific literacy. As stated by the Council for Educational Improvement and Research, science and technology are powerful forces that shape human life on Earth. They have enormous potential to make our lives better and richer, to keep our world safe and livable, and to make our societies productive and progressive. Science education needs to help fulfill the potential of science and technology by ensuring that they are used effectively, creatively, and wisely.

As stated in *Pacific Standards for Excellence in Science*, the study of science enriches peoples' lives. It opens the human mind to new aesthetic and intellectual pleasures and to a new appreciation of the beauty and precision that surrounds us. Science education empowers people to take greater control of their lives and to face problems with courage and understanding. It liberates them to imagine new questions and to set about finding new answers.

All citizens need to be scientifically literate to function effectively in an increasingly technical age and to help create and sustain a decent, just, and vigorous society. A scientifically literate person is one who understands key concepts and principles of science and uses scientific knowledge and ways of thinking in everyday life. Citizens today face a range of hard choices from the personal (how to avoid AIDS) to the global (what to do about the greenhouse effect). People who understand science are better prepared to sort fact from myth, make sensible decisions, and urge their leaders toward enlightened public policy choices.

Science education is also economically important. We will need scientifically literate people in a range of fields that are science, health, and technology related. There will be an increasing demand for workers who have flexible skills, a basic grasp of science and technology, and the ability to solve problems and think creatively. These are the things that quality science education provides.

Why Do We Need To Change How Science Is Taught And Learned?
Most schools in the USA today use a traditional approach to teach science. Science is presented as a fixed body of facts, principles, and definitions, and segregated by disciplines such as biology, chemistry, and physics. Learning is dispensed by the teacher and the textbook, with students expected to master a range of topics by listening and reading. Instead of acquiring understanding, students learn isolated bits of information such as naming the parts of a plant, labeling the nucleus in a drawing of a cell, or stating the equation for calculating density.

The conventional way of teaching science does not work for most students. Scientists, researchers, educators, and business people agree on this point. Somewhere in the middle grades students lose interest in science and by high school many find science difficult, boring, and irrelevant. Given the choice, few take advanced science courses. And the result is that most adult citizens are not scientifically literate. For example, it is not uncommon to find adults who do not know that the Earth revolves around the sun once a year or others who believe that humans lived at the time of the dinosaurs. According to many this result is due to an emphasis on covering too many topics superficially rather than in depth, seatwork over hands-on activities, memorizing rather than critical thinking, and recitation instead of well-reasoned argument.

Science is more than a body of knowledge. Science is a way of looking at the world and ordering one's experience in it. The study of science presents an opportunity to open young minds to new ideas and to equip them with the intellectual tools that will guide them as learners for the rest of their lives.

Science education is most effective when it captures the beliefs and "habits of mind" or methods of thinking that guide scientists in their own explorations of the world. What are these beliefs and methods? Among them are the beliefs that the world is understandable; that ideas are not fixed but grow and change over time; that scientific knowledge is durable; and that science cannot explain all things. Science also values certain rational methods of inquiry. These include careful observation, thoughtful analysis, healthy skepticism, the blending of logic and imagination, and the development of sound and coherent predictions and explanations.

In keeping with these beliefs and methods, good science teaching encourages students to be curious, creative, open-minded, skeptical, willing to suspend initial judgments, able to collaborate with others, and persistent in the face of failure. Research has validated several teaching strategies for developing these qualities and thinking processes. In the effective science classroom, the activity of finding out is as important as knowing the answer. By continually moving back and forth among questions, observations, and experiments, students refine and validate their hypotheses and at the same time develop good thinking skills.

Underlying Assumptions of the Standards
There have been major changes and advances in science education in the last decade that impact on the recommendations for change in the science curriculum. Recent developments in cognitive psychology, understanding of learning styles, and identification of multiple forms of intelligence emphasize learning that is hands-on, inquiry-oriented, and cooperative.

Inquiry Teaching. We now know that learners need a large amount of experience and information to understand new concepts and apply them to new situations. Thus, if true learning is to occur, concepts must be pursued in depth. Lectures are often not the most effective way to teach and too often result in the ability to say the right words without any real understanding of what they mean or how to use and apply that knowledge.

Inquiry is a multifaceted activity that involves observing, posing questions, reading accounts of others to see what is already known, designing and conducting investigations, collecting and analyzing data, interpreting findings, posing solutions to problems, using critical, logical, and creative thinking, and so on. Engaging students in inquiry enhances learning.

Constructivism. Building on the emphasis on experiential, hands-on, inquiry learning characterized by the educational philosophies of John Dewey and Jean Piaget, a new conception of learning has emerged that researchers call *constructivism*. In this view, learners build their own understandings that are complex, highly organized, and strongly tied to specific subject matter. Each learner constructs his or her own knowledge by making connections between new information and their own existing knowledge.

Learning occurs when one becomes aware of inconsistencies in his or her prior conception of the world and is helped to either abandon or restructure these concepts. Discussion among learners is essential for them to check their understanding against that of others and to construct new concepts. Teaching, then, is not as easy as giving information, but requires patient dialogue with and among students and multiple opportunities over extended periods of time to experience phenomena.

Learning Styles and the Nature of Intelligence. Educators have known for a long time that students learn in different ways, yet we teach in school as if this were not so. The concept of learning styles is very old. In more recent years the differences in the ways people learn have been researched and described by those in the neurosciences, psychology, education, and organizational development. All point to similar conclusions about the ways we perceive and process new knowledge—what has come to be called our *learning style*.

Another major influence on views of learning has been the theory of multiple intelligences developed by Howard Gardner, a cognitive psychologist at Harvard University. Gardner challenges the view of intelligence as a single ability. He defines intelligence as the ability to solve problems or fashion products valued in at least one cultural setting. The human mind, he says, is a set of at least seven intelligences keyed to doing different kinds of tasks:

- linguistic
- logical-mathematical
- bodily-kinesthetic
- spatial
- musical
- interpersonal
- intrapersonal

Gardner argues that traditional schooling develops only two of the seven kinds—linguistic and logical-mathematical—at the expense of the other five. Gardner insists that schools must center on persons, offering students choices, even within the same courses, and attending to each one personally so that all can develop their intelligences to the fullest.

The implications from this research for teaching point to the necessity of using a variety of instructional strategies in whatever we teach. Attaining understanding and abilities cannot be achieved by any single teaching strategy or learning experience. In fact, using only one teaching

strategy, no matter how skilled the teacher, results in systematically excluding as many as 70% of the students from meaningful learning.

Cooperative Learning. Social interaction is a critical part of learning. Working collaboratively in small groups is an instructional approach that provides children the opportunity to verbalize what they know and check it against what others know.

Simply put, cooperative grouping effectively promotes student learning. In all the research studies conducted thus far comparing cooperative learning with competitive and/or individualistic learning, in no case has cooperative learning been shown to be less effective and, in most cases, it was more effective in promoting student learning. Effective science instruction incorporates a variety of teaching strategies. Competitive activities are good for practice, recall, and review. Individual activities are appropriate when a student must learn a specific skill or concept and attainment of the goal is important to the student. Cooperative learning is most appropriate for activities calling for problem solving, divergent thinking, and inquiry.

Integration. An extension of the constructivist emphasis on connecting new learning to prior knowledge is an increasing recognition that science does not exist and should not be taught in isolation. Both the Association for the Advancement of Science (AAAS) and the National Science Teachers Association (NSTA) have strongly recommended that science be integrated and connected to other subject areas in elementary school and that the disciplines of science (biology, chemistry, physics, earth science) be integrated and taught each year in high school science courses. This is not only a realization of how to better teach science in elementary and secondary schools, but a recognition of how science itself has changed in the last decade, becoming increasingly interdisciplinary.

Further, there is an increasing recognition that the study of technology as it interfaces with science and society must be taught in schools. Science and technology have become inseparable. It is technology that every student interacts with every day. Yet, the study of technology is not currently part of the school curriculum in the United States.

SUMMARY

Remembering that education is a State right and responsibility, both *Benchmarks* and *Standards* set out the broad expectations for our educational systems to achieve. It is left to individual states to develop plans (usually called frameworks), programs, and teachers to achieve these expectations. But no indicators have yet been developed to tell us when we have achieved the expectations. The problem for us as educators will be how to reconcile the different documents and how to adapt them to the diversity of our communities, schools, and students.

The good news is that for the first time a consensus among scientists and science educators is emerging on what students should know and be able to do. Setting standards, however, may be the easy part. There is a naive assumption that because the standards are developed, education will improve. Achieving the standards will take intensive and lifelong professional development of teachers, new programs of instruction, and upgrading of our educational systems if we are truly to give all students an equal opportunity to achieve the standards. At this point it not clear whether our country or the individual states are willing to take on the task.

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GRADES K–5 DASH SCOPE AND SEQUENCE OF ACTIVITIES

CLUSTER	GRADE K	GRADE 1	GRADE 2	GRADE 3	GRADE 4	GRADE 5
Learning	Learning Calendar Home Learning Calendar Calendar Review Responsibility Chart Science Record Book Using Our Senses Same and Different Physical Characteristics Functions of Things Working Dictionary Wonder and Discover Book Connections Book Families Families and Helping Making Friends Being Friends School and Home Concept and Skill Inventory	Learning Calendar Responsibility Chart Planning Calendar Last Year Helping Working Together Taking Turns and Sharing Concept and Skill Inventory	Learning Calendar Last Year Aphorisms Helping Others Getting Help Making and Keeping Friends Turns School, Teacher, Friends, and Family Predictions about Tomorrow Planning for Tomorrow Thinking Library Concept and Skill Inventory	Learning Calendar Last Year Responsibility Planning Organizing Our Environment Friends Giving and Receiving Working Together Helping Myself and Others Aphorisms Next Year Science & Technology Concept and Skill Inventory	Learning Calendar Responsibility Last Year Library Working Together Things I Can Do for Myself and Others Aphorisms Planning Survival Game Concept and Skill Inventory	Learning Calendar Responsibility Library Working Together Things I Can Do for Myself and Others Aphorisms Friendship Concept and Skill Inventory
Time, Weather, and Sky	Weather Watch Beginnings Endings Day and Night Days, Weeks, and Months Moon Watch Moon Phases Seasons Clocks and Calendars	Sky and Weather Watch Rain and Streams Snow and Streams Digital Clock Hours and Minutes Time Line Sunrise and Sunset Night and Day The Sun The Seasons Making a Clock	Temperature Wind Sunrise, Sunset, and Seasons Moonrise and Moonset Rain Snow Digital Time Analog Time	Weather Temperature Wind Rain and Snow Humidity Sunrise and Sunset Moon Phases Polar Sky Model Polar Constellations Venus Eclipses	Rainfall and Snowfall Wind Direction & Speed Height of Clouds Clouds and Weather Storm Clouds Humidity and Wind Chill Lightning Weather Maps Weather Fronts Predicting Weather Flat or Round Earth? Length of Day and Night The Sun's Shadow Path The Planetarium Planets When Is It Noon? Making and Using a Sundial Seasons and the Sun Moon Phases and the Sun Eclipses	Weather Station Heat Index Weather Prediction Clouds and Fronts Triangles Gnomon Size of Earth Moon Through a Telescope How Big and Far Away Is the Moon? Paths of Celestial Bodies Models of the Solar System

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GRADES K–5 DASH SCOPE AND SEQUENCE OF ACTIVITIES

CLUSTER	GRADE K	GRADE 1	GRADE 2	GRADE 3	GRADE 4	GRADE 5
Animals	Appropriate Pets Classroom Animals Caring for Animals Living, Once-living, and Nonliving Things Animals and Plants Animal Environments Uses for Animals How Bugs Walk Parts of Bugs Parts of Mammals People Animals and Food Animals and Water Animals and Air Animal Wastes How Animals Keep Warm How Animals Keep Cool Real or Imaginary	Classroom Pets Living &and Nonliving Things Defining Living and Nonliving Things Animal Survey Animal Key Animal Needs Planning to Raise a Small Animal Building Cages Metamorphosis	Classroom Pets Classroom Aquarium External Anatomy of Fish Biological Needs of Fish Reproduction and Development of Fish Finding Insect Eggs Hatching Insect Eggs Early Metamorphosis Late Metamorphosis Collecting Spiders Insects and Spiders Spider Food Spider Care Spiders as Predators Spider Webs	Classroom Pets Raising Insects Comparing Insects Importance of Insects Frog and Toad Habitats Raising Frogs and Toads Frog Metamorphosis Importance of Frogs and Toads Toads and Insects Hatching Chicks Chick Growth Importance of Birds	Pet Care Unincubated Egg Chick Embryology Raising Small Mammals Reproduction of Pet Mammals Pet Baby Care Our Early Years The First Grade Child Development of Pets Human Development Changing Dimensions Anatomy of Fish Fish Reproduction Digestive, Circulatory, and Reproductive Systems Migration and Hibernation Fall, Winter, and Spring Birds	Pet Care Birds I Know Cells Male Urogenital System Female Urogenital System Ovulation Cycle Ovulation and Pregnancy Embryology Body Changes Bones Skeletal System Muscles Muscular System Chemistry and Bones The Senses The Eye Sound The Ear
Plants	Plant Parts Plant Environment Plant Uses Growing Bean Sprouts Plants and Water Gardening	Plant Identification Plant Survey Plant Pressing Plant Key Plant Needs Plant Life Cycle Edible Plant Parts Plant Parts Animals Eat	Soil Making Soil Soil and Plants Soil Uses Finding Soil Pipes and Water Moving Water: Gravity Moving Water: Pumps Vegetable and Flower Gardens in a Bucket Rooting Stems Rooting Bulbs and Tubers Roots and Water Growing Root Vegetables Tree Planting	Garden Planning Garden Preparation Watching Garden Soil Making Artificial Soil Testing Soil Soil and Water Garden Planting Garden Care Watering Systems Garden Invaders Controlling Insects Garden Harvesting Flowers Seeds Pollination	Annual, Biennial, and Perennial Plants Fungi	Annual, Biennial, and Perennial Plant Project Tree Harvesting Tree Planting Tree Observation Measuring Trees Age of Trees Trees, Shrubs, and Grasses Grasses: Why Do They Grow There? Roots Soil Conservation
Food and Nutrition	Bean Sprout Salad Drinks Flour and Bread Familiar Foods Favorite Foods New Foods	Food Groups Cooking Measuring Volume	Supermarket Survey Food Preference Food Groups New Foods Properties of Foods Changing Flavor Milk, Butter, and Cheese Energy from Food	Nutritious Food Selection Plants for the Garden Class Feast Drying and Pickling Foods Preserving and Rotting Supermarket Game Pricing Foods Food Ads	Nutrients Mechanical Digestion Chemical Digestion Food Groups Preserving Foods	Nutrients Nutrients and Cells Food Labeling

GRADES K–5 DASH SCOPE AND SEQUENCE OF ACTIVITIES

CLUSTER	GRADE K	GRADE 1	GRADE 2	GRADE 3	GRADE 4	GRADE 5
Health and Safety	Growth Chart Tooth Chart Tooth Care Exercise Germs Washing Hands Bathrooms and Basins Aprons Fountains and Faucets Getting Sick Feeling Sick Going to the Doctor What Doctors Do Going to the Hospital Raincoats Testing Raincoats Wet and Cold Keeping Warm Indoors Hand and Foot Protection Getting Lost	Growth Chart Tooth Chart Brushing Teeth Chewing Air and Breathing Getting Hurt Staying Healthy Safety Rules	Growth Chart Tooth Chart Tooth Care Getting Hurt Getting Sick Staying Well Classroom and Playground Safety Fire Safety Using 911	Growth Chart Tooth Chart Breathing Air Anatomy of Breathing Lung Model Lungs and Smoking Breathing and Pulse Heart, Veins, and Arteries Heart, Lungs, and Exercise Disease Transmission Trash and Sanitation Helpful Drugs Proper Drug Use	Growth Chart and Area Measurement Tooth Chart Safety Gear Safety and Putting Out Fires Making a Fire Things That Burn Smoking and the Lungs Alcohol, Tobacco, and Drugs	Growth Chart and Area Measurement Tooth Chart Alcohol, Tobacco, and Drugs Sexually Transmitted Diseases Safety Devices Smokers' Surveys Smoking Laws Alcohol Laws Chris's Story The Parents' Story Intoxication Drug Laws
Wayfinding and Transportation	Right and Left Sunrise Sunset North and South Rising Moon Setting Moon Home Location Sidewalks & Walkways Roads Traffic Simulation Traffic Rules Mapping	Pacing North, South, East, and West Home Map Distance Making a Boat Making a Lake The Great Regatta Floating and Sinking Draining a Lake	Transportation Systems Making Race Cars Racing Cars Roads Building a Village Pedestrians in the Village Bikes in the Village Cars in the Village Bikes and Trikes Belts and Pulleys Fast and Slow Pulleys Gears and Wheels	Garden Mover Propeller-Driven Message Center Propeller-driven Boat Delivery Systems	Boat Design Wind and Sails	Where in the World Are We? Planetarium Mapping the Sky The North Pole, Equator, and Ecliptic Where Is Earth?

GRADES K–5 DASH SCOPE AND SEQUENCE OF ACTIVITIES

CLUSTER	GRADE K	GRADE 1	GRADE 2	GRADE 3	GRADE 4	GRADE 5
Energy and Communication	Energy Making Things Move Making Things Stop Turning Things Off Turning Things On Repairing Things	Temperature of Things Master Thermometer Hot and Cold Sources of Energy	Sun and Direction Mirrors and Sunlight Clouds and Sunlight Comparing Temperatures Eclipses	Shadow, Light, and Bubbles Wind and Heat Wind Pulls and Pushes Propellers Driving Propellers Waterwheels Propellers in Water Heliograph Speaking Tube String Telephone Energy Definitions	Push-Pull Measuring Tool Friction Streamlining Pressure, Sharp Edges, and Points Energy of Falling Objects Circles and Speed	Pushes, Pulls, & Forces Teeter-Totters The Balance Wheels and Axles Levers Arms and Jaws Inclined Planes and Screws Block and Tackle Magnetic Pushes and Pulls Magnets and Compasses Magnetic Fields Forces Projects
Conservation, Recycling, and Decomposition	Decomposition Waste Disposal Recycling Project Making Paper	Classroom Resources Conserving Energy Conserving Water Decomposition and Unearthing Decomposition and Reburial Recycling	Fall Unearthing Fall Burying Spring Unearthing Spring Burying Pollution Survey Aluminum Recycling Connections	Making Compost Watching Compost Animals in Compost Using Compost Fall Unearthing and Burial Spring Unearthing and Burial	Unearthing and Burial Recycling Project	Class Recycling Project Class Conservation Project Decomposition and Archeology Pollution Project
Matter, Space, and Construction	Cubby Organization Patterns in Puzzles Making Puzzles Making Envelopes Making Boxes and Bags Volume of Boxes and Bags Packing and Storing Linear Measurement	Meter-string Can Outdoor Study Area Mapping Testing for Water Measuring Volume Plumbing Water Systems Air Bubbles in Water and Air Building with Air Floor Plan Cardboard House Plan Making a Cardboard House Painting the House Furnishing the House Sewing and Weaving Warming andCooling Lighting the House	Desk Organization Notebook Organization The Balance Meter-string Can Measuring Volume	Acidic and Basic Soil Acids and Bases Acid and Base Reactions Diluting Acids and Bases Acid and Base Interactions Dissolving Things Things in Liquids Crystals Rain in a Jar Supermarket Planning Supermarket Construction Measuring Devices Safety Equipment	Linear Measurement Volume Measurement Mass Measurement Collecting Rocks Hardness of Rocks Specific Gravity Rocks and Sharp Edges Making Tools from Rock Clowns: Things That Float Clay Fire and Pottery Air and Fire Fire and Oxygen Properties of Gas	Linear Measurement Volume Measurement Mass Measurement Camera Obscura Controlling Light with Lenses Making a Telescope Stabilizing the Telescope Making a Microscope Making a Hygrometer Making a Barometer

GRADE 6 SCOPE AND SEQUENCE OF ACTIVITIES

Learning	Time, Weather, and Sky	Animals	Plants	Food and Nutrition
Learning Calendar Last Year Mars Mission Tomorrow The Work World Goals Crash Simulation Mars Compact Martian Simulation The Mission Conference Concept and Skill Inventory	Weather Station Weather Around the United States Weather and Local Climate Wind Hypotheses Producing Winds Air Pressure and Altitude Wind and Water Altitude and Temperature Models of Air Climatic Regions Climate of Mars	Animal Care Raising Fish Raising Worms Food Chains	Hydroponics Algae Nutrients and Biological Waste Water Pollutants	Nutrient Tables The Kilocalorie Weight Watching Meal Planning Food for Space Fish and Algae for Dinner
Health and Safety	**Wayfinding and Transportation**	**Energy and Communication**	**Conservation, Recycling, and Decomposition**	**Matter, Space, and Construction**
Growth Chart Tooth Chart Safety Disease Literature Sanitation Disease Prevention and Treatment Sexually Transmitted Diseases Drug Abuse Prevention and Treatment Alcohol and Tobacco Addiction, Prevention, and Treatment Environmental Disease Transmission, Prevention, and Treatment Exercise and Health and the Mars Mission	Flying Airplanes Flying Rockets Spacecraft The Orbit of Mars What Path to Mars?	Rocket Propulsion Magnetism Electrostatics Electrical Circuits Rock Formation Metals from Ores Asymmetrical Levers	Recycling Project Conservation Decomposition: A Summary Pollution	Making Measuring Equipment Making a Balance Making an Electroscope Making Electromagnets and Current Indicators Electric Cells Making an Electric Motor Making an Electric Signaler Making a Martian Survival Habitat

DASH CLASSROOM COMPONENTS

Inventor's Box

The Inventor's Box is a device used for initiating and facilitating the process of invention through the distribution of materials. It is simply a box labeled "Inventor's Box." Suggested items to go into the Inventor's Box are found in the Teacher's Guide under the Materials section.

There are several strategies for using the Inventor's Box with large groups. First, before starting the activity, have a student unpack the box one item at a time and record the inventory on the chalkboard or chart paper. Everyone then knows what is in the box, eliminating the need to rummage through the box to discover its contents. Second, distribute identical Inventor's Boxes to each group or to small groups to share. Third, divide materials by categories into several labeled Inventor's Boxes—one for tools, one for containers, and so on. Older students can restock the items they have used, particularly those things that can be recycled from home.

Often the Inventor's Box is used not only to distribute materials but also to stimulate ideas during the invention process. Often available materials will suggest ideas to a stalled student or group. Additional items can be put into the box when they are requested or if an idea for an additional item occurs to the teacher after an activity has begun. Teachers are inventors, too! Occasionally the teacher may wish to limit the materials to be used for a particular activity by restricting the students to using only those things found in the box.

Concept Mapping

Concept mapping is a technique for determining the students' knowledge of a particular idea or concept. Mapping can be used before or after introducing a concept. It can also be used in creating working definitions that are recorded in the Working Dictionary and in identifying related ideas that are recorded in the Connections Book.

The students begin with pictorial concept mapping in kindergarten. Their first map might be about a concept such as weather or pets. The teacher can begin by asking about class pets and then about the students' own pets. As the students come up with ideas about pets, they are asked to draw or cut out pictures about their ideas. The drawing is usually done on a small piece of paper. For certain concepts such as plants, real objects can be used. The pictures are glued to a large sheet of chart paper with the word PETS written in the center. Lines are then drawn from each picture to the word PETS to show their connections to the concept. The students' pictures may be labeled by the teacher or the students themselves. As they learn more about pets, the students may add new ideas to the concept map.

In the second stage subcategories are added. If the students are mapping PETS, the teacher might have them regroup their pictures by kinds of pets and needs of pets. Then the words KINDS and NEEDS would be connected to the concept PETS in the center of the paper. Next, the pictures of different kinds of pets would be arranged around the word KINDS and biological requirements such as air, water, and food around NEEDS. Finally, connecting lines and labels would be added.

More experienced students working in small groups can be assigned subcategories that are assembled around the major concept. The concept of insects with its subcategories of habitat, development, body parts, kinds, and uses is a good example for using this technique.

Lines on concept maps show the connections between pictures or words. On a concept map of pets, NEEDS would be connected to FOOD which could be connected to SEEDS. Lines drawn from a seed picture would connect with all the different animals that eat seeds.

The categorizing, connecting, and labeling processes get more complex over time. Eventually, the entire map is done using only words and webbing. This typically occurs sometime in grade 2 or 3. By grade 3 students are normally able to make individual concept maps.

In DASH, the concept map is also used as an assessment tool. Used prior to instruction, the concept map provides insight into what students already know. Used after instruction, it provides a way of summarizing and recording what was learned.

Working Definitions and the Working Dictionary

A working definition generally has three kinds of parts. It tells the CATEGORY to which the thing being defined belongs and its FORM and FUNCTION. The form is a description of the thing's properties or characteristics. The function tells what the thing does or how it is used. As the students attempt to define a concept using category, form, and function, keep in mind that distinguishing between form and function is not always as easy as it appears. The more complex an idea is, the more difficult it usually is to determine its category. A kindergarten example of a working definition for pet might be "a pet is an animal (category) like a dog, cat or fish (form), that we take care of and love (function)."

A plant might be defined by kindergartners as "a living thing (category) that usually has roots, a stem, leaves, sometimes flowers and is partly green

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(form)." "Plants grow, die, and make seeds (function)" may come later. The students begin to construct working definitions of their developing concepts in kindergarten. Often younger students will not include all three parts in their definitions. Keep in mind that this is a working definition. These definitions are meant to be revised as the students' knowledge about the concept develops. The current definition is only a reflection of the students' knowledge at a particular point in time. By grade two in DASH, students usually have a good understanding of the working definition and its parts. They require little or no cueing to construct their definitions.

The Working Dictionary takes many forms. Some primary teachers put all the definitions into a big book format. Teachers in upper grades may have the students create a section in their Science Record Book for the dictionary. Some teachers hang their working definitions together on a chart stand. Other teachers keep their dictionaries in a computer file. Some teachers have their students arrange the definitions alphabetically, others chronologically, and still others by category or cluster.

One technique is to begin a new topic of study with a concept map to determine what the students already know. As the students move through DASH activities and their understanding develops, additions can be made to the concept map. As the topic comes to a close and a working definition is called for, return to the concept map. Ideas on the concept map can be classified as to form and function, giving the students a wealth of information to draw upon to create or revise their working definition.

The Working Dictionary is also an assessment tool. The openness of the dictionary approach enables teachers and students to gain a clearer picture of what they know at any given time.

Wonder and Discover Book

Student questions are a vital part of DASH. Questions asked by students can give the teacher insight into the thinking processes and levels of understanding of students. Students often ask questions at inopportune moments. The questions may not pertain to the topic at hand or may be at a level that requires more in-depth investigation than is presently being pursued. The Wonder and Discover Book provides the teacher with a way to acknowledge the questions without breaking the flow of the lesson.

When a student asks a question that is beyond the scope of the current activity, the question is recorded on a new page in the Wonder and Discover Book along with the student's name and the date. When any student discovers something about the question, it is recorded on the same page with that student's name and the date. The process continues for as long as the students pursue the question. There should only be one question on each page to accommodate the ongoing discovery. Additional pages can be added for a particular question if necessary.

A class book with open access keeps students involved in this investigative process. Occasionally, debates between students on certain topics are recorded. The actual format of the Wonder and Discover Book may be a big book in the lower grades or a three-ring binder as the students get older. Computer files can be used. Students can also keep a section in their Science Record Book to record their personal questions and discoveries.

Students are encouraged to discuss their questions with their parents or other experts, to read, to experiment, and to do whatever will help them find answers to what they are wondering about. Many questions are not resolved during the course of a single school year. These should be passed on to the next level teachers. This can be done by storing the Wonder and Discover Book in the library or by having the students copy their unanswered questions at the end of the year and store them in their Science Record Books.

The Wonder and Discover Book is also an assessment tool. It enables the students to record questions and ideas that relate to one another and provides a rich resource for further investigations. More important, the Wonder and Discover Book provides a way of recording and assessing the kinds of questions that students have about their learning.

Connections Book

The purpose of the Connections Book is to provide a way for the students to connect what they are learning in school to their out-of-school environment. The Connections Book is introduced in kindergarten and used throughout the DASH program. The book is used when the students have a fairly good grasp of the current concept they are investigating. The students are encouraged to reflect upon what they have been studying and connect it to what they already know or are familiar with. Younger students may need help by asking such questions as "Where else have you observed this?" and "What uses does this have?" After some discussion, their ideas are recorded. These ideas become the basis for the Connections Book. They are reviewed periodically and additional connections are recorded. The students are further encouraged to look for relationships between DASH concepts within the different clusters and activities and for connections with other school subject areas.

The form of the Connections Book varies from teacher to teacher and grade to grade. As long as the connections made by the the students are recorded in some way, the objective is achieved. In the early primary grades, the Connections Book may be in a big book format. For older

students, a section can be set aside in their Science Record Book to record their personal learning connections. The Connections Book can also be kept in a three-ring binder or in a computer file. There should be one concept on a page so that later additions can be recorded. All entries should be dated so the students have a record of their learning over time.

The Connections Book is also an assessment tool. The teacher now has a technique for identifying and recording how student knowledge is developing and especially the students' ability to use that knowledge both in school and out of school.

Science Record Book

The Science Record Book is each student's personal collection of data, ideas, plans, and other important information. It may also contain sections for the Working Dictionary, the Wonder and Discover Book, and the Connections Book. Ideally, the Science Record Book is kept from year to year and becomes a record of the students' work throughout their elementary experience.

The particular format of the Science Record Book varies depending on classroom storage space and available materials. It may be a folder, a student-constructed book, or a three-ring binder. Indexes for each cluster and additional sections for the Working Dictionary, Connections Book, and so on are also helpful.

The Science Record Books are reviewed occasionally to eliminate unnecessary items. This is particularly important at the end of the school year before the books are stored in the library or passed on to the next year's teachers. Some records that are kept from year to year include height and weight charts, hand and foot tracings, and tooth charts. Data on long-term activities such as decomposition are also retained. Other records are kept as determined by the teacher and students. Students who move to other schools or non-DASH classrooms can take their books home. Their Science Record Books can become the basis for home projects.

The Science Record Book is an assessment tool. It is a major part of the portfolio of student accomplishment and development.

Class Data Book

The Class Data Book is a place to store all the class charts and graphs for easy access. It may be held together using multiple skirt hangers (the kind with pincer clips), a hanger with clothespins, a hanging flip chart frame or rack, or a big book with a temporary binding such as large Bulldog clamps. The purpose of the Class Data Book is to store class data for future reference.

The Class Data Book is an assessment tool. It is a portfolio of both individual student and class accomplishment and development.

THE DASH LEARNING CALENDAR

One of the most successful components of the *DASH* (Developmental Approaches to Science, Health, and Technology) program is the *DASH* Learning Calendar. This calendar is a day-to-day record of data and significant science, health, technology, and other activities reported graphically on a continuous sheet of paper.

The feature that makes the calendar noteworthy is its capacity to prompt students into recalling in considerable detail curricular events for the entire school year. Using the calendar, teachers introduce long-term observational experiences that involve correlation, cause and effect, sequence, generalization, and prediction, processes not normally intensively developed.

A look at a typical *DASH* kindergarten or grade one class will illustrate how the calendar is used. When the door opens in the morning, students check the class responsibility chart and begin their first tasks. While some students feed animals and care for plants, a small team gets a wind sock, another a thermometer, and both teams go outside to make measurements. Other students already are working on the day's calendar panel, recording the date and drawing in the phase of the moon and symbols for the weather.

Shortly, the wind team returns and records the wind speed by drawing the angle at which the wind sock was blown. Then comes the temperature team which records the outside temperature in Celsius and Fahrenheit. These records reflect an emphasis in the *DASH* primary program on astronomy, weather, and seasons.

As a last activity before going home, recorders tell the class which science activities and other events of the day they have selected to represent in pictograms. The teacher asks whether there are other things that should be drawn, ensuring that crucial happenings are not lost.

A typical day's panel might include Sara's portrait and a birthday cake, a hose showing the garden being watered, a nest with a filling egg, representing a tragedy to a bird family in a nearby tree, and a computer screen with numbers showing the introduction of a new computer game.

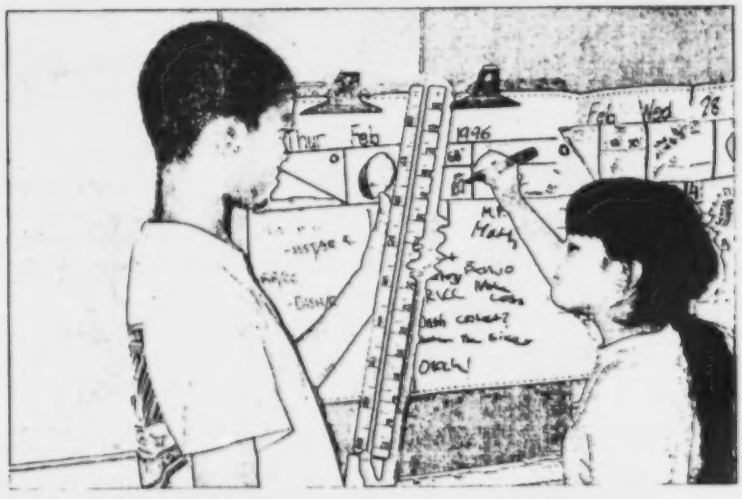
When sufficient information has been collected to find patterns, the calendar is unrolled with great ceremony and expectation. Daily events are recalled and correlations and generalizations are made. By mid-kindergarten, the sequence of the moon's phases is recognized and students can predict when the next new moon will occur. Temperature, wind, and weather are related to seasons, steps in growing plants in a bucket are identified, and animal care procedures are spoken about with authority. By physically walking up and down the calendar, students gain a haptic and visual sense of long and short intervals of time, as well as a sense of past, present, and future.

By the end of the year the calendar stretches 200–300 feet. Though the extent of the recall of individual students varies, the collective group recollection of pictograms will be 85–95% of all events recorded. Thus, in a cooperative teaching setting, the calendar provides a vehicle to give a class working access to the major happenings of the school year.

Two models of the calendar now exist The first is a continuous sheet of heavy-grade butcher paper in a double roll, like a Grecian scroll. The second is heavy-duty fan-folded computer paper, specially cut to reduce the possibility of tearing. This latter model is used both as a book and a continuous sheet.

History of the DASH Learning Calendar

Evolution of the calendar reveals something of the process of curriculum development. The idea of a continuous record of student work in a calendar form was first suggested by Frank Pottenger to Ann Baldwin Taylor and her staff for testing at the Carnegie Mellon Children's School in the fall of 1986. Reports in the spring of 1987 indicated that the class record, kept in the teacher's own writing,



DASH students record information on learning calendar

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worked as an excellent memory repository for the teacher, but when used to help students recount events, was only marginally helpful.

In the fall of 1987, the calendar idea was modified. Logos were developed by *DASH* staff members Karen Yamamoto and Don Buchholz to record moon phase, weather, and wind speed. Carol Brennan, the University of Hawaii Laboratory School K-1 *DASH* teacher, introduced the calendar in her class using the logos for data collection and a short-phrase record of major curricular events. As before, the intent of the calendar was to give the teacher a record of events to be used in directed review.

Shortly, Carol added pictorial representations to her written account. Immediately, there was an increase in the capacity of students to recall the events associated with the graphics. Here was the breakthrough! Looking back on the first calendar, we find that by the beginning of October, the record was kept almost exclusively in pictograms.

Carol used the butcher paper model of the calendar. At the mid-year unrolling it stretched about 100 feet down the hallway. With great pride, kindergartners and first graders were taking adults up and down its length, pointing out what they had been doing all year. The amount of recall and the detail of recall from these simple graphics was arresting.

In the summer of 1988, some 50 kindergarten and first grade field-test teachers associated with ten national universities were trained in the use of *DASH* materials. During the 1988-89 school year, monthly teleconferences were used to follow the progress of their teaching. A point of regular comment was the success of the calendar in getting students to remember classroom events. From those conferences the following generalizations have developed about the management of the calendar.

- The calendar should be kept up daily.
- As soon as possible, responsibility for recording information should be given to students.
- Pictograms used by recorders should be explained to the rest of the class on the day they are drawn.
- Students should be rehearsed in the content of the calendar at least once every few months.

A Possible Explanation

Most children in grades K and 1 are seldom able to respond satisfactorily to a parent's inquiry, "What did you do in school today?" However, they are able to answer the question, "What was put on the *DASH* calendar today?" and to elaborate on their response.

It is suggested that this success of the *DASH* Learning Calendar in stimulating recall may be explained as follows. Most children in grades K and 1 are still in the process of mastering language and are not yet fully using language as a primary mechanism to record events in memory. Even though children have begun to record events linguistically, the form of that record may not embrace the same aspects of those events that an adult would. Therefore, answers to questions of an interrogating adult may not be in the children's linguistic record, and they can't respond as the adult expects them to.

Further, the question "What did you do in school today?" requires that the child play back mentally a connected narrative of events of the past day. Such capacity for narration seems to develop after considerable language sophistication has been achieved and may be in part independent of language acquisition. The child who describes the kindergarten day with a single statement, "Sara had a birthday party" has probably not yet learned how to rewalk mentally through the detail of events leading up to and following Sara's party.

In contrast, visual memory is developed in very early childhood. A kindergarten student has considerable facility in using it. Pictograms appear to act as cues to access the mental record of visual information. These pictograms are discrete, but rich in association. By selecting several events to be registered pictorially on the calendar, narration is not required to account for major happenings of the day since these events are already registered on the calendar. Once the visual record is triggered by a pictogram, most children have no problem in verbally describing the associated events, because of their inherent power of visual memory.

While the *DASH* Learning Calendar enhances recall because of the nature of its pictograms, it also becomes a tool to learn how to connect events through narration covering both short (daily) and long (weeks and months) time periods. The calendar holds a record of curricular events that have been intentionally selected for their natural connectivity. Therefore, the calendar becomes a vehicle to practice mentally walking backward in time, connecting present and past events through correlation and generalization, and forward in time, connecting past, present, and future events through prediction, hypothesis, and fantasy.

Reprinted from Science Education Newsletter, October 1990

DASH LEARNING CALENDAR

(K–6) Day, Date, Month, Year
(K–6) Special Events: Birthdays, Holidays, School Events

Temperature			Weather	Wind	Astronomy
(K)	C	F	Logos	Speed	Moon Phase Season
(1)	In/Out			Direction	Sunup/down Solstice/Equinox
(2)	High/Low		Rain/Snow	Beaufort	Moonrise/set Eclipse
(3)			Humidity Comfort Scale	NE/SW NW/SE	Polar Constellations Venus
(4)			Clouds Fronts Predictions	Wind Chill	Constellations Planets Gnomon
(5)			Dew Point Air Pressure		Tides Solar System
(6)			Global Climates		Mars Simulation

(K–6) What did I learn in school today?

NEWS:		
	(K–2)	Local weather events
	(3)	National weather events and health news Global weather events
	(4)	Local and national weather maps Science and technology articles
	(5)	Laws affecting science and technology
	(6)	Global science and technology

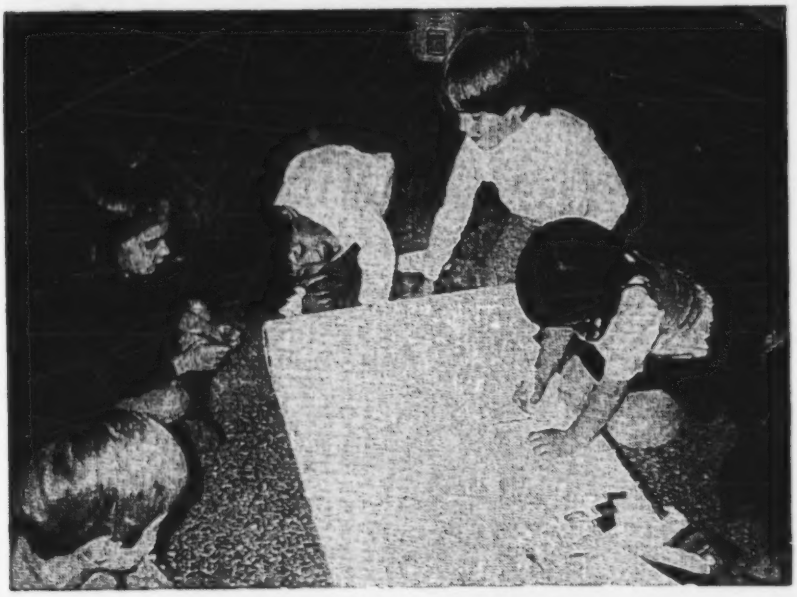
THE COLLABORATIVE CLASSROOM

This era of school reform has caused us to reflect on how we teach as well as what we teach. Research on multiple intelligences, learning styles, cognitive development, and cultural differences has made educators more acutely aware of the differences in learners and thus the necessity to teach differently if we are to truly educate those in our charge. Two of the areas receiving much attention are the roles of communication and collaboration in learning. We are beginning to see that not just some, but all students benefit by interacting with others in learning situations.

Current views on learning share some common observations about successful learners and meaningful learning. Successful learners have considerable content knowledge which they can use with fluency and authority. They are self-regulated. That is, they are aware of what they know, as well as their limitations, and constantly engage in self-analysis. Successful learners know a number of strategies for learning various subjects, for problem solving and decision making, and for thinking creatively. They know that much of their success depends on interaction with others, and they have well-developed interpersonal skills.

Effective communication, then, is essential to becoming a successful learner. It is primarily through dialogue and interaction that students become knowledgeable, self-regulating, strategic, and empathic. Further, the recent emphasis, particularly in science and math, on constructivist philosophy, which calls for involving students in real-world tasks and linking new information to prior knowledge, requires effective communication, interaction, and collaboration between teachers, students, and others.

It is primarily through dialogue and interaction that students become knowledgeable, self-regulating, strategic, and empathic.



Research Base for Collaboration

Vygotsky, a developmental theorist and researcher who worked in the 1920s and early '30s, has influenced some of the current research on collaboration between students and teachers and on the role of cultural learning and schooling. His principal premise is that human beings are products not only of biology, but also of their human cultures. Intellectual functioning is the product of our social history, and language is the key mode by which we learn our cultures and through which we organize our verbal thinking and regulate our actions.

Inner Speech. Children learn when they engage in activities and dialogue with others, usually adults or more capable peers. Children gradually internalize this dialogue so that it becomes inner speech, the means by which they direct their own behavior and thinking. For example, as adults use language such as *That piece does not fit there; let's try it someplace else*, children may initially just imitate this strategy. However, they gradually use it to regulate their own behavior in a variety of contexts. Eventually, this dialogue becomes internalized as inner speech.

There seems to be a general sequence in the development of speech. When alone, very young children tend to talk about what they have done after they complete an activity. Later, they talk as they work. Finally, they talk to themselves before they engage in an activity. Speech now has assumed a planning function. Later they internalize this speech. Inner speech—conversations we carry on with ourselves— begins as a social dialogue with other people and is a major mode of learning, planning, and

self-regulation. When people are asked to solve difficult problems or to perform difficult tasks, inner speech will go external, that is, take its more primitive form. In other words, people frequently talk to themselves when they face a problem. This externalization of inner speech is often observed in children. When they engage in familiar, simple activities, they usually do so without talk, but faced with difficult tasks, they may whisper or talk out loud to themselves. Adults do this too. When they are faced with perplexing or unfamiliar tasks—such as figuring out how to work a VCR—they often talk themselves through such tasks.

Vygotsky noted that children interacting toward a common goal tend to regulate each other's actions. Other researchers have observed that when students work together on complex tasks, they assist each other in much the same way adults assist children. In such tasks, dialogue consists of mutual regulation. Together, they can solve difficult problems they cannot solve working independently.

Scaffolding and Development. As children learn, effective teachers change the nature of their dialogue so that they continue to support the child but also give the child increasing responsibility for the task. For example, the adult might say *Now, see whether you can find the next piece of the puzzle yourself.* Jerome Bruner and his colleagues called this *scaffolding*. It takes place within the child's *zone of proximal development*, a level or range in which a child can perform a task with help. (Piaget refers to this as *teachable moments* when adults stretch a child's capacity but stay within what they are capable of understanding.)

The zone of proximal development, scaffolding, and dialogue are especially useful concepts for frameworks for school learning. Vygotsky observed that effective teachers plan and carry out learning activities within children's zones of proximal development through dialogue and scaffolding.

Connecting School Learning to Everyday Life. Vygotsky also provides us with a framework for thinking about an important function of teaching and the multicultural perspective. His research suggests that school learning enables students to connect their "everyday concepts" to "scientific concepts." In other words, schools help students draw generalizations and construct meaning from their own experiences, knowledge, and strategies. Knowledge learned in the community and knowledge gained from school are both valuable. Neither can be ignored if students are to engage in meaningful learning.

Effective teachers help students make these connections by scaffolding and dialogue. In fact, these are the essence of mediating. Teachers plan learning activities at points where students are challenged. Teachers plan activities and experiments that build on the language of students' everyday lives through familiar examples and behaviors, analogies and metaphors, and the use of commonly found materials. Teachers demonstrate, do parts of the task students cannot do, work collaboratively with students where they need help, and release responsibility to students when they can perform the task independently.

Palinscar and Brown. Palinscar and Brown have applied Vygotsky's theories about dialogue and scaffolding to classroom instruction. They reasoned that if the natural dialogue that occurs outside school between a child and adult is so powerful for promoting learning, it ought to promote learning in school as well. In particular, they were interested in the planning and self-regulation such dialogue might foster in learners as well as the insights teachers might gain about their students' thinking processes as they engage in learning tasks.

One particular application was in reading comprehension for students identified as poor readers. The researchers proposed that poor readers have had impoverished experiences with reading for meaning in school and concluded that they might learn comprehension strategies through dialogue. To encourage joint responsibility for dialogue, they asked students to take increasing responsibility for leading discussion, i.e., to act as the teacher. This turn-taking is called *reciprocal teaching*.

The four comprehension strategies that are stressed are predicting, question generating, summarizing, and

clarifying. The "teacher" leads dialogue about the text. Predicting activates students' prior knowledge about the text, helps them make connections between new information and what they already know, and gives them a purpose for reading. Students also learn to generate questions themselves rather than responding only to teacher questions. Students collaborate to accomplish summarizing, which encourages them to integrate what they have learned. Clarifying promotes comprehension monitoring. Students share their uncertainties about unfamiliar vocabulary, confusing text passages, and difficult concepts.

Reciprocal teaching has been successful, but only when teachers believe the underlying assumption that collaboration among teachers and students to construct meaning, solve problems, and so forth, leads to higher quality learning. Believing this is only a beginning. Engaging in true dialogue requires practice for both teachers and students. However, the principles of collaborative dialogue and scaffolding for purposes of self-regulated learning ought to be effective across many content areas.

Cooperative Learning. Cooperation, a form of collaboration, is "working together to accomplish shared goals" (Johnson & Johnson, 1989, p. 2). Whereas collaboration happens in both small and large groups, cooperation refers primarily to small groups working together.

Research strongly supports the advantages of cooperative learning over competition and individualized learning in a wide array of learning tasks. Compared to competitive or individual work, cooperation leads to higher group and individual achievement, higher-quality reasoning strategies, more frequent transfer of these from the group to individual members, more metacognition, and more new ideas and solutions to problems. In addition, students working in cooperative groups tend to be more intrinsically motivated, intellectually curious, caring of others, and psychologically healthy. That is not to say that competition and individual work should not be valued and encouraged, however. For example, competition is appropriate when there can be only one winner, as in a sports event, and individualistic effort is appropriate when the goal is personally beneficial and has no influence on the goals of others.

Unfortunately, simply putting students in groups and letting them go is not enough to attain the outcomes listed above. Indeed, many teachers and schools have failed to implement cooperation because they have not understood that cooperative skills must be learned and practiced, especially since students are used to working on their own in competition for grades. At least three conditions must prevail, according to Johnson and Johnson, if cooperation is to work. First, students must see themselves as positively interdependent so that they take a personal responsibility for working to achieve group goals. Second, students must engage in considerable face-to-face interaction in which they help each other, share resources, give constructive feedback to each other, challenge other members' reasoning and ideas, keep an open mind, act in a trustworthy manner, and promote a feeling of safety to reduce anxiety of all members. Heterogeneous groups of students usually accomplish this second condition better than do homogeneous groups.

Third, students must have effective group process skills if the first two are to prevail. In fact, group skills are never "mastered." Students continually need to reflect on their interactions and evaluate their cooperative work. For example, students need to learn skills both for accomplishing tasks, such as summarizing and consensus taking, and for maintaining group cohesiveness, such as ensuring that everyone has a chance to speak and to make compromisses.

Difficult as it may be to implement cooperative learning, those who have done so are enthusiastic. They see improved learning, more effective social skills, and higher self-esteem for most of their students. In addition, they recognize that our changing world demands more and more cooperation among individuals, communities, and nations, and that they are indeed preparing students for this world.

Collaborative Classrooms

Collaborative classrooms seem to have four general characteristics.

The first two capture changing relationships between teachers and students. The third characterizes teachers' new approaches to instruction. The fourth addresses the composition of a collaborative classroom.

Shared Knowledge. In traditional classrooms, the dominant metaphor for teaching is the teacher as information giver; knowledge flows only one way, from teacher to student. In contrast, the metaphor for collaborative classrooms is shared knowledge. The teacher has vital knowledge about content, skills, and instruction and still provides that information to students. However, collaborative teachers also value and build upon the knowledge, personal experiences, language, strategies, and culture that students bring to the learning situation.

Additionally, complex thinking about difficult problems, such as world hunger, begs for multiple ideas about causes, implications, and potential solutions. In fact, nearly all of the new curricular goals are of this nature—for example, mathematical problem solving—as are new requirements to teach topics such as AIDS. They require multiple ways to represent and solve problems and many perspectives on issues.

Shared Authority. In collaborative classrooms, teachers share authority with students in very specific ways. Collaborative teachers invite students to set specific goals within the framework of what is being taught, provide options for activities and assignments that capture different student interests and goals, and encourage students to assess what they learn. Collaborative teachers encourage students' use of their own knowledge, ensure that students share their knowledge and their learning strategies, treat each other respectfully, and focus on high levels of understanding. They help students listen to diverse opinions, support knowledge claims with evidence, engage in critical and creative thinking, and participate in open and meaningful dialogue.

Suppose, for example, the students have just read a chapter on colonial America and are required to prepare a project on the topic. While a more traditional teacher might ask all students to write a ten-page essay, the collaborative teacher might ask students to define the product themselves. Some could plan a videotape; some could dramatize events in colonial America; others could investigate original sources that support or do not support the textbook chapter and draw comparisons among them; and some could write a ten-page paper. The point here is twofold: (1) students have opportunities to ask and investigate questions of personal interest, and (2) they have a voice in the decision-making process. These opportunities are essential for both self-regulated learning and motivation.

Teacher as Mediator. As knowledge and authority are shared among teachers and students, the role of the teacher increasingly emphasizes mediated learning. Successful mediation helps students connect new information to their experiences and to learning in other areas, helps students figure out what to do when they are stumped, and helps them learn how to learn. Above all, the teacher as mediator adjusts the level of information and support so as to maximize the ability to take responsibility for learning.

Heterogeneous Grouping. The perspectives, experiences, and backgrounds of all students are important for enriching learning in the classroom. As learning beyond the classroom increasingly requires understanding diverse perspectives, it is essential to provide students opportunities to do this in multiple contexts in schools. In collaborative classrooms where students are engaged in a thinking curriculum, everyone learns from everyone else, and no student is deprived of this opportunity for making contributions and appreciating the contributions of others.

Thus, a critical characteristic of collaborative classrooms is that students are not segregated according to supposed ability, achievement, interests, or any other characteristic. Segregation seriously weakens collaboration and impoverishes the classroom by depriving all students of opportunities to learn from and with each other. Students we might label unsuccessful in a traditional classroom learn from "brighter" students, but, more importantly, the so-called brighter students have just as much to learn from their more average peers. Teachers beginning to teach collaboratively often express delight when they observe the insights revealed by their supposedly weaker students.

Teacher as Facilitator

Facilitating involves creating rich environments and activities for linking new information to prior knowledge, providing opportunities for collaborative work and problem solving, and offering students a multiplicity of authentic learning tasks. This may first involve attention to the physical environment. For example, teachers move desks so that all students can see each other, thus establishing a setting that promotes true discussion. Teachers may also wish to move their desks from the front of the room to a less prominent space.

Additionally, teachers may structure the resources in the classroom to provide a diversity of genres and perspectives, to use and build upon cultural artifacts from the students' homes and communities, and to organize various learning activities. Thus, a collaborative classroom often has a multiplicity of projects or activity centers using everyday objects for representing numerical information in meaningful ways and for conducting experiments that solve real problems. These classrooms also boast of a rich variety of magazines, journals, newspapers, audiotapes, and videos that allow students to experience and use diverse media for communicating ideas.

Another way that teachers facilitate collaborative learning is to establish classrooms with diverse and flexible social structures that promote the sort of classroom behavior they deem appropriate for communication and collaboration among students. These structures are rules and standards of behaviors, fulfilling several functions in group interaction and influencing group attitudes. Particular rules depend, of course, on the classroom context. Thus, teachers often develop them collaboratively with students and review or change them as needed. Examples of rules are giving all members a chance to participate, valuing others' comments, and arguing against (or for) ideas rather than people. Examples of group functions are asking for information, clarifying, summarizing, encouraging, and relieving tension. To facilitate high-quality group interaction, teachers may need to teach, and students may need to practice rules and functions for group interaction.

Finally, teachers facilitate collaborative learning by creating learning tasks that encourage diversity, but which aim at high standards of performance for all students. These tasks involve students in high-level thought processes such as decision making and problem solving that are best accomplished in collaboration. These tasks enable students to make connections to real-world objects, events, and situations in their own and an expanded world and tap their diverse perspectives and experiences. Learning tasks foster students' confidence and at the same time are appropriately challenging.

Teacher as Model

In collaborative classrooms, modeling serves to share with students not only what the teacher is thinking about the content to be learned, but also the process of communication and collaborative learning. Modeling may involve thinking aloud (sharing thoughts about something) or demonstrating (showing students how to do something in a step-by-step fashion). In terms of content, teachers might verbalize the thinking processes they use to make a prediction about a scientific experiment, to summarize ideas in a passage, to figure out the meaning of an unfamiliar word, to represent and solve a problem, to organize complicated information, and so on. Just as important, they would also think aloud about their doubts and uncertainties. This type of metacognitive thinking and thinking aloud when things do not go smoothly is invaluable in helping students understand that learning requires effort and is often difficult for people.

With respect to group process, teachers may share their thinking about the various roles, rules, and relationships in collaborative classrooms. Consider leadership, for example. Teachers might model what they think about such questions as how to manage the group's time or how to achieve consensus. Similarly, showing students how to think through group situations and problems of communication is as invaluable as modeling how to plan an approach to an academic problem, monitoring its progress, and assessing what was learned.

Teacher as Coach

Coaching involves giving hints or cues, providing feedback, redirecting

students' efforts, and helping them use a strategy. A major principle of coaching is to provide the right amount of help when students need it—neither too much nor too little—so that students retain as much responsibility as possible for their own learning.

For example, a collaborative group of junior high students worked on the economic development of several nations. They accumulated a lot of information about the countries and decided that the best way to present it was to compare the countries. But they were stymied as to how to organize the information so they could write about it in a paper, the product they chose to produce. Their teacher hinted that they might use a matrix—a graphic organizer they had learned—to organize the information. When the group finished the matrix, the teacher gave them feedback. In so doing, he did not tell them it was right or wrong, but asked questions that helped them verbalize their reasons for completing the matrix as they did. The principle the teacher followed was to coach enough so that students could continue to learn by drawing on the ideas of other group members.

Student Roles

Students also assume new roles in the collaborative classroom. Their major roles are collaborator and active participator. It is useful to think how these new roles influence the processes and activities students conduct before, during, and after learning. For example, before learning, students set goals and plan learning tasks; during learning, they work together to accomplish tasks and monitor their progress; and after learning, they assess their performance and plan for future learning.

Goal Setting. Students prepare for learning in many ways. Especially important is goal setting, a critical process that helps guide many other before-, during-, and after-learning activities. Although teachers still set goals for students, they often provide students with choices. When students collaborate, they should talk about their goals. For example, one teacher asked students to set goals for a unit on garbage. In one group, a student wanted to find out if garbage is a problem, another wanted to know what happens to garbage, a third wanted to know what is being done to solve the problem of garbage. The fourth member could not think of a goal, but agreed that the first three were important and adopted them. These students became more actively involved in the unit after their discussion about goals and at the end of the unit could better evaluate whether they had attained them.

Self-Regulated Learning. Self-regulated learning is important in collaborative classrooms. Students learn to take responsibility for monitoring, adjusting, self-questioning, and questioning each other. Such self-regulating activities are critical for students to learn today, and they are much better learned within a group that shares responsibility for learning. Monitoring is checking one's progress toward goals. Adjusting refers to changes students make, based on monitoring, in what they are doing. For example, a group of students decided that the sources of information on the Civil War they selected initially were not as useful as they had hoped, so they selected new materials.

Assessment. While teachers have assumed the primary responsibility for assessing students' performance in the past, collaborative classrooms view assessment much more broadly; that is, a major goal is to guide students from the earliest school years to evaluate their own learning. Thus, a new responsibility is self-assessment, a capability that is fostered as students assess group work.

In a collaborative classroom, assessment means more than just assigning a grade. It means evaluating whether one has learned what one intended to learn, the effectiveness of the learning strategies, the quality of the products and decisions about which products reflect one's best work, the usefulness of the materials used in a task, and whether future learning is needed and how that learning might be realized.

Persistent Issues

When teachers and schools move from traditional to collaborative instruction, several important issues are likely to arise. They are important concerns for teachers, administrators, and parents.

Classroom Control. Collaborative classrooms tend to be noisier than traditional classrooms. This is a

legitimate issue for a number of people. Some teachers believe that noisy classrooms indicate lack of discipline or teacher control. In such situations, they argue, students cannot learn.

Collaborative classrooms do not lack structure. Indeed, structure becomes critical. Students need opportunities to move about, talk, ask questions, and so on. Thus, the noise in a smoothly running collaborative classroom indicates that active learning is going on. However, students must be taught the parameters within which they make their choices. Rules and standards must be stressed from the beginning, probably before any collaboration is initiated, and reviewed throughout a school year.

Preparation Time. Teachers and administrators may believe that new lesson plans must be formed for these classrooms. To a certain extent, they are correct. But many teachers already have created engaging units and activities that are easily implemented in a collaborative classroom. Furthermore, teachers can begin slowly, making changes in one subject area or unit within a subject area, probably one they are already very comfortable teaching, and then add other subjects and units. Teachers can also share their plans with each other. Indeed, if we expect students to collaborate, we should encourage teachers to do the same!

Individual Differences. A major question people have concerns the advantage collaboration affords gifted or high-achieving students. There are two tough issues here. First, many teachers do not believe that low-achieving students have much to contribute to the learning situation; in effect, that they have no prior experiences or knowledge of value. Second, teachers worry that high-achieving students will be held back.

In response to the first concern, many collaborative teachers have expressed surprise when seemingly less-able students had insights and ideas that went way beyond what teachers expected. Further, if each student contributes something, the pool of collective knowledge will indeed be rich. In answer to the second concern, data suggest that high-achieving students gain much from their exposure to diverse experiences and from peer tutoring. Also, students who may be high achieving in one area may need help in other areas.

Teachers and others also wonder whether shy students can fully participate in a classroom that depends so much on dialogue. These students might feel more comfortable talking in small groups that share responsibility for learning. Furthermore, interaction between learners can happen in ways other than oral dialogue, for example, writing and art.

Grouping. A related concern is that many schools are structured homogeneously so that an individual teacher cannot form heterogeneous groups without involving changes in the entire school. A whole class of "low" readers are taught by one teacher, "average" by another. High school tracks are not conducive to collaborative learning and require system-wide restructuring. Individual teachers or groups of teachers can initiate dialogue on the problem, however.

Grading. This concern is a difficult one to solve unless major changes in other areas of schooling are also undertaken. Students are used to being graded for individual work; parents expect to know how their students fare in school. School staff and state departments depend on traditional assessments. In collaborative classrooms, it is often difficult to assign individual grades. Some teachers give group grades, but many students and parents are uncomfortable with these.

Ideally, assessment practices should be changed so that they are consistent with collaboration, with a new view of learning and with a thinking curriculum. In the meantime, effective ways have been developed whereby individual students can be evaluated in collaborative classrooms. For example, David Johnson and Roger Johnson, as well as Robert Slavin, advise making individuals responsible for subtasks in group work and then determining both group and individual grades.

Summary

The reluctance people feel when asked to make major changes in the way they do things is clearly the most serious issue of those discussed here. Hardly a person exists who eagerly gives up familiar ways of behaving to attempt something that is unknown and is likely to have many challenges of implementation.

This problem requires leadership, support, and time to address. Staff development needs to address teachers' concerns. We urge that educators first examine their assumptions about learning and then consider new curriculum guidelines. There is an intimate relationship between one's definition of learning, one's view of the content and scope of curricula, and instructional practices. Examining one's assumptions honestly and forthrightly in a supportive group often spurs educators to change. The already-convinced must allow time for the less-convinced to reflect and grapple with implications for the views expressed. They must also accept the possibility that some educators may not change. We are urging that students be treated with such respect; we must urge the same respect for adults.

Source: Tinzmann, M.B., Jones, B.F., Fennimore, T.F., Bakker, J., Fine, C., & Pierce, J. (1990). The Collaborative Classroom: Reconnecting Teachers and Learners. Elmhurst, IL: North Central Regional Educational Laboratory.

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THE DASH BEGINNING-INQUIRY TEACHING MODEL

Developmental Approaches in Science & Health (DASH) is the newest science project of CRDG. It is being designed as a sequential, hands-on program for grades K–6 that integrates science, health, and technology.

This article discusses the ways broad historical currents have been used in shaping the structure of the DASH curriculum.

DASH reflects the content, methodologies, and operating skills of the physical, biological, and earth sciences; of the disciplines of health, body conditioning, and medicine; of the technologies of agriculture, industry, communication, and transportation. Selection of content, methodologies, and skills around which activities are constructed has been strongly influenced by their historical development.

DASH Historical Model

DASH has used a loose historical sieve to help determine content and skills appropriate for students at different stages of cognitive development. This strategy grew out of the observation of educational theorists that children's capacity to master the concepts and skills of technology and science seems to parallel the historical sequence in which these concepts and skills developed.

First-emerging concepts and skills, both in the intellectual development of children and in the history of technology and science, are associated with satisfying basic needs such as food, water, air, sanitation, and body protection. Curricular content embracing these concepts and skills has the highest utility in the life of children and constantly commands their attention.

DASH first builds out of the technology, health, and science aspects of these conceptual fundamentals as they are reflected in the child's world. It then progressively explores the foundations of modern science as it supports the ever more sophisticated world of technology and information that opens to children as they expand their knowledge and skills.

DASH Teaching Models

Again using history as a guide, DASH has adopted a set of teaching models selected to support a particular kind of teaching situation. These include its Beginning-Inquiry Teaching Model, Experimental-Inquiry Model, Aphoristic-Authority Model, and Contextual Skill Development Model.

The DASH Beginning-Inquiry Teaching Model

The DASH Beginning-Inquiry Teaching Model has four steps, one or more of which may be completed in a single activity. These steps are 1) activation, 2) exploration, 3) application, and 4) explanation.

1. **Activation step.** During this step, the stage is set for the inquiry to follow. In DASH, the stage may be set by the teacher's creating a problematic situation or a direction for investigation. This is what usually happens when a new topic of inquiry is to be launched.

   Basic to activation is developing the motivation and the logic for starting new work. This step may also evolve out of the logic of the sequencing activities and be impelled by the children's curiosity.

2. **Exploration step.** In this step, children do a range of activities that give them information about their problematic situation. Because exploration is finding out about things and how to do things, what children do to gain such knowledge and expertise varies from situation to situation.

   Exploration always engages students in observation, often drawing on long-term data collection as well as association and integration of new information with existing mental frameworks. It usually takes the form of manipulation and testing. It may be totally self-directed, or it may be assisted by classmates or the teacher. DASH explorations often take up much of the school year; in some cases they require collecting data over more than one year. Out of any long-term exploration may come more than one application.

3. **Application step.** In this step, children respond to their problematic situation; they devise and invent devices, procedures, rules, and aphorisms that have some real or simulated utility. Findings from the exploratory step are employed as soon as possible so that children can relate their observations, manipulations, and testing to situations that are useful and interesting to them.

4. **Explanation step.** In this step, children advance generalizations and interpretations for what they have done. In this beginning model, children's explanations are likely to be speculative, based on intuitive common sense. More exploration or design and experimental testing of ideas may come later.

   This step is not dedicated to stating a "right explanation" but is directed toward seeking a "workable explanation." Two things are required of an explanation: 1) that it account in a non-animistic way for the events observed and 2) that it be recorded as part of the class

record or the child's personal record. (Class records are kept for K–1; personal records are kept for grades 2–6.) In DASH, working definitions and explanations are considered tentative.

Comparison of Models

It is informative to compare the DASH model with the most prominent current elementary teaching model, that generated by Robert Karplus. See Figure 1. The Karplus model uses stages rather than steps to describe the sequence of mental operations children are assumed to go through as they internalize information. It is usually referred to as a "learning" rather than a "teaching" model. It labels what is perceived to be happening to students as they learn, and it specifies what the teacher does to bring about the desired developmental progression.

In contrast, the DASH model reverses the emphasis, specifying a sequence of characteristic operations that teachers can facilitate. These operations produce evidences of children's learning in the form of identification of potential areas of inquiry and of applications of skills, inventions, and explanations.

"Step" in the operations of the DASH model, therefore, is teacher language. To make the comparison easier, I will use the neutral term "phase" to refer to both stage and step.

The Karplus model is a three-phase model. When phases 1 and 2 of DASH are collapsed, the DASH model is seen to use the same operations as the Karplus model. Both depend on "stage setting" or laying out the study agenda and free inquiry by children.

The major difference is the point at which application occurs. In the DASH model, application occurs after the activation/exploration phase. In the Karplus model, it occurs after the explanation phase. In DASH, application is the vehicle used to develop the basis for understanding an emerging explanation. In the Karplus model, application is a way of demonstrating understanding of an already stated explanation.

The DASH Beginning-Inquiry Teaching Model assumes that children in grades K–3 are assimilating new information and that at this early period of concept development they are most often dealing with situations around which they are establishing first explanations. The Karplus model assumes that children have explanations that must be accommodated to the accepted scientific viewpoint.

A striking feature of the DASH model is that children have greater control over generating inquiry and knowledge. Inventions and explanations are in the children's control in DASH; in the Karplus model, they are generated by the teacher.

Rationale for the DASH Beginning-Inquiry Teaching Model

DASH used historical clues to develop its inquiry model. Records of beginning science in natural history, astronomy, and meteorology come to us from possibly a thousand years before the Christian era. Predating these early records by eons are artifacts—tools, goods, and structures that tell us humans were technologists and engineers long before they were scientists.

Invention Is an Innate Capacity of Humans

Rocks, sticks, caves, streams, skins of animals, and so on, all suggest to humans ways of crafting useful things. Without understanding the explanatory science that undergirds an invention, an exploring child will shortly make a cairn of loose rocks, a digging tool of a stick, a mat of an animal hide, a shelter of a cave, a feed source for a network of diversion ditches from a stream of rainwater. In all these responses to natural phenomena there seems to be an intellectual

	PHASES		
Karplus	EXPLORATION (Teacher sets stage. Student inquires into problematic situation.)	EXPLANATION (Teacher explains scientific views. Student learns scientific explanation.)	APPLICATION (Teacher creates new problems. Student solves new problems.)
DASH	ACTIVATION/ EXPLORATION (Teacher/Student sets stage. Student freely inquires into problematic situation.)	APPLICATION (Student invents solution. Teacher facilitates.)	EXPLANATION (Student suggests explanations. Teacher facilitates.)

Figure 1. Phases of the Karplus and DASH models

bridge, a common insight, reaching back to the technological creations of our remotest ancestors.

Technology Remains the Pathfinder
Even today, technological invention often precedes scientific understanding and explanation. Whole fields of science owe their existence to such inventions as the telescope, microscope, spectroscope, radio, cyclotron, and so on. It follows that invention, ("application" in the language of the DASH model) has often preceded "explanation" and that application is often the more basic task.

Common-Sense Science Is Natural to Early Elementary Years
There is another dimension to the DASH teaching model suggested by history. In its beginnings, science was descriptive, speculative, and rooted in common sense. Its validity was found in logical debate. Only since the sixteenth century has experimentation been added to logical debate as part of the process for validating explanation. Many modern scientific explanations were preceded by speculative, common-sense explanations that have not held up under experimental testing. Given the freedom to create explanations, these same common-sense explanations of antiquity are the ones that lower elementary children usually produce.

Common Sense Is a Source of Insight
Although common sense produces explanations that may not be verified in the clearer light of experimentation, common sense is a precious source of insight to be nurtured. Since explanations in DASH are recognized as tentative, the unverified, common-sense explanation is open to correction in later experimentation. Explanation in DASH evolves. It can wait to be corrected, just as modern explanations await the potential impact of disconfirming experimentation and further explanation.

An example will help show this. In DASH, children begin to study the moon in kindergarten. The moon is seen to rise in the east, pass overhead, and set in the west. By the end of the year, children recognize that the moon has a regular cycle of about 28 days, divided into quarters of 7 days each.

In like fashion, first-grade children follow the transit of the sun, measuring the changing length of night and day and relating it to the seasons.

Common sense quickly turns DASH students into Ptolemaists. Certainly, this is an approach that astronomers who speak of sunrises, sunsets, and transits—all non-Copernican terms—cannot reasonably reject.

It is the DASH position that for the child to understand modern astronomy and its metaphors, it is best to become a Ptolemaist first and a Copernican later, when they need modern solar models. This model comes in fifth grade in the DASH sequence.

The DASH student lives the history of science and technology.

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"What Do You Think?" The Next Steps

When a student asks a DASH teacher a question, the usual response is, "*What do you think?*" But if teachers stop with this question, some students get frustrated. What comes next?

First, urge the student to venture an answer to your question. After the student gives an answer, ask the next question, "*How can you find out about or test your idea?*".

Once the student has looked for an answer or tested an idea, move to the third question, "*What did you find out?*" This sequence often leads students to answer their own original questions.

Why ask these particular questions? Asking "*What do you think?*" promotes thinking and moves students along the road to constructing their own understanding of how the world operates. Responsibility for learning lies with the student, where it belongs if the student is to mature into a lifelong learner.

This questioning strategy supports the DASH model of inquiry. A student takes the initial step by formulating a question or a problem. The teacher's response "*What do you think?*" gets the student to reflect on what they already know. Once a student offers an answer, the question "*How can you test your idea?*" moves the student to the stage of application—using the known to design a way to test the answer.

When a first attempt doesn't produce an answer or a solution, the student gets a chance to try again. This is the exploration/application phase of the inquiry. The teacher can now support the inquiry by asking probing questions or perhaps by offering Socratic clues. Even when the test produces no answer, it still yields information helpful in devising other tests or seeking other answers. Students may move back and forth between exploring and applying (typical of the early DASH inquiry model) and between hypothesizing and experimenting (common in the upper-grade model).

Once a student proposes an answer, the DASH teacher moves to the next step, "*What did you find out?*" This critical question causes the student to organize an answer or explanation—a process of integrating new knowledge with prior knowledge.

Responding to a request for information with these three questions—

- What do you think?
- How can you find out about or test your idea?
- What did you find out?

—moves students through the DASH inquiry process and helps them construct an understanding of their world.

DASH Lower Grade Inquiry Model	Key Questions	DASH Upper Grade Inquiry Model
Explore	What do you think?	(Anomaly) Hypothesize
Apply	How could you find out or test your idea?	Experiment
Explain (Describe, Show, Generalize)	What did you find out?	Explain (Interpret)

FACILITATING DISCUSSION IN INQUIRY SCIENCE

Introduction

In most classrooms, discussion plays a very important role in the learning process. In inquiry instruction, it is essential. Discussion enables students to articulate what they know, to tell others what they know, and to listen to other points of view. In inquiry classrooms where collaborative groups engage in learning activities, there must be extensive discussion between students to carry out their work successfully. Just having the students complete investigations does not constitute teaching science, for students do not discover science concepts and generalizations on their own. The teacher's role in guiding discussion about work is of key importance. The teacher must assist students in making connections between what is already known and the new knowledge concepts, applications, or skills being developed.

Discussion is generally used at the beginning and end of laboratory or field investigations. Initially, it is the teacher's responsibility to generate and stimulate class discussion. Ideally, as the year progresses, increasing responsibility will be assumed by students as they become more aware of the place of discussion in inquiry, in the development of concepts, and in the development of thinking.

Discussion may be used for many different purposes, including

- Giving guidance and direction to investigation.
- Reviewing concepts and skills already in the students' backgrounds.
- Introducing and identifying new problems or areas for investigation.
- Generating hypotheses.
- Planning experimental procedures.
- Analyzing and interpreting data.
- Assessing and revising hypotheses.
- Formulating and analyzing conclusions.
- Summarizing activities or experiments.

Discussion in Inquiry Science

Inquiry science provides frequent opportunities for creative expression that the teacher and students should recognize and seize upon. Laboratory and field investigations provide unique opportunities for students to invent, create, make decisions, and try out their own ideas. Discussion opens these inventions, decisions, and ideas to the scrutiny of others. Teachers must hold high expectations of students' creative abilities and communicate them to the students. Research shows that high expectations stimulate greater achievement by all students, especially low achievers.

Discussion and Inquiry. Development of thinking skills and understanding of concepts requires discussion. The teacher's role is critical in moving students from what they already know to richer and deeper understanding about the world around them. In inquiry classes this is accomplished by asking appropriate questions.

Taba has described three levels of thinking: recalling, processing, and applying. These levels can be elicited through appropriate use of questioning strategies. Developing higher-level processing and application thinking skills is not only desirable but essential to students' growth as inquirers. Studies of questions asked by teachers indicate that as many as 70–80 percent of the questions were based on recall. Research has shown that questions calling on higher-level thinking skills result in higher-level responses on the part of students. However, a mix of questions requiring thinking at all levels seems to result in the greatest student growth.

Discussion is central to the development of inquiry skills such as observing, inferring, verifying, and hypothesizing. Post-laboratory and post-field discussion is especially important. Nelson and Abraham have suggested that the apparent failure of school science inquiry programs in the past could be attributed to the lack of such discussion. Typically, teachers tell students what they should have observed or inferred.

Cognitive Conflict in Inquiry. A special discussion technique in developing inquiry skills is the creation of cognitive conflict. The moment of disagreement or conflict is to be cherished, for such conflict motivates students to seek resolution and develop skills of problem solving. Teachers can intentionally build cognitive conflict through questioning. Palmer has suggested several ways for the teacher to do this:

- Comparing students' explanations.
- Feigning great surprise at a faulty or correct explanation.
- Posing an impossible event implied by a position taken by a student.
- Establishing expectancy for an outcome that testing will not support.
- Not accepting a rote answer, but asking for supporting evidence.
- Accepting all observations and explanations until two are given that are contradictory to one another, then building a discussion on the conflict.

The Facilitator

Leadership of discussion usually rests with the teacher. However, students can develop discussion skills and should be encouraged to do so. Discussion is appropriate to both large- and small-group interaction. What follows is a series of guidelines for teachers and students to use in leading discussion. The discussion

leader is referred to here as the facilitator. In the role of discussion leader the facilitator proposes, suggests, invites, questions, and is generally concerned not only with the content of the discussion, but also with the feelings of group members. The facilitator tries to promote meaningful group interaction, stimulate responses, and help the group generate its own data. Ways to help bring about this kind of group interaction are described below.

Encourage Participation. If a person is reluctant to enter the discussion, an invitation to disagree, recap, summarize, or just jump in and contribute may be all that is needed. Such invitations act to encourage by letting individuals know that their contributions are needed. Involvement helps individuals feel that they are members of the group.

Group discussion often involves disagreement. Take advantage of such disagreement and encourage active participation by seeking divergent ideas. Group members should be invited to give their views. Most importantly, they should be asked for evidence to support their views. Disagreement is particularly fruitful if there is an accepting attitude toward differences in opinion, no pressure for closure, no voting, no concern when an impasse is reached.

In inquiry science, a point of impasse is to be specially nurtured, for the crucial question "How do we test our ideas?" can then be asked. A side benefit accrues as students learn early on that in solving technological and social problems there are no easy answers or no one "right" answer or conclusion. They will also find that there are different ways to process, interpret, and apply available data.

Support Group Members. Be supportive of all participants in a discussion. The discussion area must be a safe place to enter. Be particularly supportive of those who have problems entering into the mainstream interaction such as

- The student who is suddenly unable to answer when asked for a response.
- The shy student who offers irrelevant information on the first attempt.
- The unpopular student whose every comment is attacked by someone.
- The student whose ideas are always just given by the last speaker.
- The student who needs a helping, supportive hand.

Handling Error. When a person makes an error of fact, ask another question to allow the person to correct the error. If the students are accustomed to discussing points of disagreement, ask the group for a different point of view. Whenever possible, refrain from direct correction to avoid inhibiting participation. When students become apprehensive about the reception of their thoughts, they begin to offer only those answers that they consider acceptable to the teacher or their peers.

Remember that everyone has numerous "false" ideas that can be identified only when they are expressed. If students never opened their mouths or wrote down their thoughts, no one would ever discover what "right" and "wrong" ideas they have. Getting the wrong ideas out into the open is one advantage of discussion. But in order for this to occur, a safe, accepting environment must be established in the classroom. When the teacher recognizes that a large segment of the group displays serious misunderstandings about a particular topic, it becomes possible to plan learning activities to rectify these misunderstandings.

Listen Attentively. One of the most difficult things for a facilitator and a group member to do is to listen—to really hear what is being said. Spoken words do not always convey what is actually intended. In addition, whatever one hears is filtered through one's own thoughts and experiences and, therefore, is often distorted. An effective facilitator must consciously listen to statements made by group members and help all group members understand them.

Listening may be passive and silent. Saying nothing indicates acceptance. Keeping quiet and allowing students to say what they choose encourages them to say more. Nonverbal clues such as smiling and nodding also indicate acceptance of ideas. In addition, verbal clues can be used to assure the speaker that someone is really interested and listening. Such phrases as "Uh-huh," "I see," and "Anything else?" indicate to the speaker that you are listening.

Listening attentively may also involve interaction with the speaker. The facilitator may rephrase information to the speaker to clarify or gain greater insight into the true meaning of the speaker's statements. Such feedback tends to ensure understanding of what is being communicated.

It is equally important that students learn to listen to the quesitons of the facilitator. A simple but useful technique is to state a question before identifying who is to answer it. This causes everyone to listen intently because they may be called upon to respond.

- When we opened the pea pod, what did you find, Mary?

If the student's name is mentioned first, the other students can relax because they know that Mary must cope with the question.

- Mary, when we opened the pea pod, what did you find?

Alternative Facilitator Roles

The facilitative role that is perhaps most familiar to teachers is that of the directive facilitator. The directive facilitator guides or leads members of a group to a predetermined point, for example, invention of a generalization. To be effective, the directive facilitator must have some knowledge of the content being investigated and

must plan ahead how discussion will progress. The skills necessary to be an effective directive facilitator are difficult for students to learn or feel comfortable with at this point in their development, since this role does require foreknowledge of the content being discussed.

There is much discussion in the classroom, however, in which there is no predetermined end point. The object of such discussion is to work with the unknown, to bring out as many ideas as possible, in short, to keep discussions open ended. Such discussion requires different leadership skills—those of a nondirective facilitator. The nondirective facilitator encourages individuals to participate in the group discussion without guiding the direction of the discussion. This role is usually not as familiar to teachers as that of the directive facilitator. It requires the teacher to be accepting and trusting of the students' ideas while at the same time keeping the discussion focused on a particular topic.

Because the role of the nondirective facilitator is not dependent on content knowledge, this role is more easily learned and practiced by students than the directive facilitator role. Only as students are provided an opportunity to learn leadership skills can they be expected to accept responsibility for leading group discussion in the classroom.

The following pages describe some of the techniques that are characteristic of directive and nondirective facilitator roles. The roles are not mutually exclusive. It may, therefore, be difficult at times to determine which role a group leader is exhibiting since some of the same techniques are often employed successfully by both kinds of facilitators.

The Directive Facilitator

This section includes discussion techniques designed to help a directive facilitator deal more effectively with comments and responses to questions asked of a group. It is important that the directive facilitator accept all responses, encourage participation, support group members, and listen attentively to what is said.

Questions that Develop Content

In addition to setting and maintaining a favorable social-emotional climate, the directive facilitator must keep the discussion moving in the desired direction. This is most effectively done by asking questions. However, asking good questions requires planning and practice. There are many different kinds of questions that can be asked. Some are appropriate at one point in a discussion, but inappropriate at others. The effective facilitator knows how to ask good questions, what kinds of questions to ask, when to ask them, and what kinds of responses to expect.

The facilitator should decide beforehand what questions to ask. Writing them down often helps to clarify direction and increase the probability of clear, well-stated questions that can be acted upon. Several different types of questions are described below.

Clarifying Questions. Asking for clarification is one way of responding to confusion. The clarifying question can elicit the meaning of unfamiliar terms or the rephrasing of disconnected, fuzzy statements to ensure common understanding, for example,

- Can you be more specific?
- What do you mean by "things"?
- Can you say that in another way?
- Can you give us an example?

Extending Questions. An extending question pushes for elaboration. The facilitator may be probing for alternatives, additions, analogies, and explanations.

- Can you think of any other differences?
- Can you tell us some more about soil erosion?
- Is there anything else that you would like to mention?
- Does heat have properties that are similar to those of any other thing you know?

Focusing Questions. Focusing questions initiate discussion or produce major shifts in a discussion. Such questions are often prefaced by a summarizing statement:

- What we said we want to do first is analyze the data.
  Let's start by looking at the first two columns of the data sheet.
  Can anyone see anything in common to both columns?
- Let's go back to our chart.
  How are these animals alike?

Refocusing is essential at times, especially for people who wander off the track easily. The focus question may be repeated or written on the board. Rewording may be necessary to start the flow of discussion if the original phrasing is misunderstood by those attempting to respond. Most refocusing is related to maintaining the discussion of the topic.

- Now, what were we discussing a moment ago?
- How does that relate to the subject?
- What was the question we were discussing?

Lifting Questions. The technique of lifting the level of discussion is the most difficult questioning technique to learn and is, as a result, most often overlooked or avoided by a facilitator. Questions can be preplanned to lift the discussion away from the concrete toward the broad generalization by using "why" type questions.

A facilitator's artistry is reflected in how opportunities to lift the level of discussion are seized. Lifting questions appropriate to the response of a person usually cannot be prepared in advance because the direction of any one person's contribution is unpredictable. However, through one or a series of questions, the facilitator may

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often assist a person to build a chain that ends in a connection, a generalization, an inference, a hypothesis, an explanation, a problem statement, or a definition.

- Are heat and light connected in some way?
- From the two lists, can you find a common property?
- Accepting that the properties listed on the board are common to both, what can we say about gases and liquids?
- What hypothesis might be made to explain how winds are formed?
- How would you define life?
- What problem have we found in this?

Summarizing Questions. When a person elaborates on an idea at great length, meaning gets buried. It is often a good idea to ask for a succinct restatement or summary.

- How can we put what you have just stated on the board?
- Can you give us the main idea of what you are saying?

Use of summary questions at the end of a discussion or class period can be one of the most exciting and important parts of each lesson. Such questions are designed to allow participants to discuss the implications of what they have learned and to generate their own ideas and generalizations about what they have done.

The Nondirective Facilitator

The nondirective facilitator does not direct the discussion, but rather tries to promote group responses, help generate data, and develop values. The nondirective facilitator does not impose personal interpretations, values, or answers on the group, but helps the group to generate consensus. As with the directive facilitator, the nondirective facilitator is concerned that every member's data and opinions be included and accepted, but remains personally neutral on matters concerning the group task. The nondirective facilitator will employ some of the types of questions characteristic of the directive facilitator, but in general the questions are more open-ended and offer less guidance during discussion. The nondirective facilitator role may be used by students when the class is meeting in small groups.

Following are some things that the nondirective facilitator should keep in mind when leading group discussions.

Plan Ahead. Always plan carefully beforehand how to lead the discussion. Think about where the group is headed or what it is attempting to do. List questions that elicit what members know and how this will relate to what they are trying to achieve.

State the Problem Clearly and Concisely. As soon as possible after the group has convened, try to get the members to define the problem or question to be discussed. A sharply defined question helps focus group attention on the objectives to be met. See that the topic is clear to everyone. Help the group to clarify any misconceptions.

Suggest a Problem-Solving Approach. Ask for ways to address the question, issue, or problem. Solicit suggestions for changes or alternative ways of approaching the problem. Get commitment and acceptance from the group to adhere to a plan of action, then proceed to follow that plan. The facilitator should be open to midstream improvements in the plan if they are not totally disruptive. There will always be a call for reasonable judgment.

Accept and Clarify Communication. In general, try to accept all responses and statements. This is important since it encourages individuals to contribute further. Relate one idea to another. Accept incomplete ideas. Ask for further development of the idea from the individual or the group.

If I understand it correctly, your idea would add to Ann's by . . . .

Point out when an individual's contribution is cut off and invite completion.

I'm afraid we may have cut Karen off. Karen, did you have any more you would like to add?

Be Nonjudgmental. The way in which a facilitator responds to a question or statement can either enhance communication or prevent it. Judgmental responses, those that reflect a person's personal opinions and values, may show either approval or disapproval. Examples of both kinds of statements are given below.

Approval: That is a great idea. I'm certainly glad you are in our group.

Disapproval: That wasn't a very smart thing to say.

Both kinds of judgmental statements inhibit individual participation. Some people will not contribute out of fear of disapproval; others may not contribute because they are afraid they won't receive approval.

Nonjudgmental responses do not reflect opinions or values and, therefore, contribute to the establishment of a more accepting social climate within the group. They may seek more information, reflect a person's feelings, or paraphrase content.

- When was the last time that happened?
- Is the lack of action frustrating you?
- In other words, do you think the data are questionable?

Accept Feelings. Accept feelings as well as content. When needed, clarify feelings of the individual or group.

- Could you explain how you feel about that?

When there is conflict in a group, someone, rather than an idea, is often under attack. People tend to say "I don't agree with YOU" rather than "I don't agree with your IDEA." Emotional feelings often get confused with intellectual content.

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The facilitator should try to interpret both the ideas and the feelings being communicated. Try to see the situation objectively, but also interpret feelings as objectively as possible.

- You feel frustrated? Uneasy? Confused?
- What is it about *this idea* you disagree with?

Facilitators should also accept their own feelings. Rather than expressing feelings emotionally or exploding with them before the group, try to interpret your own feelings and state them as objectively as possible.

- I feel frustrated at not being able to progress more quickly.

Encourage other group members to express their feelings in the same way.

Keep the Discussion Focused. In any group interaction, the discussion may drift from the main topic from time to time. Point out that the discussion has drifted and restate the original question or paraphrase it.

- My understanding is that we were discussing. . . .

Interrupt the long-winded speaker as tactfully as possible to invite contributions from the other group members. If some important point is being neglected, get at it by asking such questions as

- Is there anything else that should be considered?
- Has anything been left out?

Summarize and Clarify Direction. Take time every so often to get the group to draw loose ends together. Get as fair and accurate a summary as possible. Call attention to unanswered questions.

- Are there any questions that are still unanswered?
- What should our next step be?

Allow time for group members to discuss the implications of what they generated during the discussion. During the summary activity, participants should state generalizations about what they have done. Close the discussion by having the group summarize their major accomplishments.

Techniques that Require Caution

Some discussion techniques can have either positive or negative effects on group participation and discussion. Used appropriately, these techniques can help the facilitator guide discussion and learning and challenge group members to think carefully about their responses. Used inappropriately, these same techniques may destroy group interaction and limit discussion. Such techniques, therefore, must be used with a thorough knowledge of their effect and with caution.

Verbal Rewards. The directive facilitator commonly employs verbal rewards both to support group members and direct discussion. This is a very subtle area, but with certain guidelines, verbal rewards can be very effective in facilitating discussion. The tone of expression is very important, since the emotional overtone of a question or response to a question can either encourage or inhibit participation. An example of inappropriate verbal reward is given below.

T: What industries would we find in Honolulu?
S: Pineapple packing.
T: All right, what else?
S: Shipping.
T: Very good, Johnny! (You guessed what was on my mind.)

Such an exchange is likely to inhibit people who do not feel that they are very good at guessing what is on the teacher's mind. Generally, avoid the over-reward—the overly explicit or overly generalized reward.

Excellent, Frank.
Wonderful!
Tremendous work!
Very good!

Over-reward has the effect of inhibiting, rather than freeing the discussion. Many students will be reluctant to respond, fearing that they will not receive it.

The most effective rewards are an implied acceptance of the people and their ideas. The facilitator could have said "Any others?" with an encouraging look in response to Johnny's answer. A response such as this keeps the possibility of discussion open, rewards the student by accepting contributions, yet allows termination if no additions are made.

Verbal Repetition. Repeating is a common technique used by many people leading group discussion. This occurs when the facilitator repeats everything each person in the group says.

T: What did you see?
S: A hawk.
T: A hawk. Did anyone see anything else?
S: A dove.
T: A dove. Did anyone see anything else?
S: A deer.

Repeating may facilitate discussion of certain topics with some groups since it allows students to hear what has been said. Students often do not realize the import of what they are saying unless they have an opportunity to hear what it sounds like. Repeating allows students to hear what they have said and also allows other members of the group to think about what has been said.

Repeating, however, may detract greatly from the effectiveness of the leader and the discussion. It may restrict group interaction since all responses must go through the facilitator. This, in turn, may also mean that no one has to listen to anyone else since the facilitator will repeat everything anyway.

If repeating becomes limiting to good discussion, there are several things that can be done:

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- A simple technique to avoid repeating is to ask the person to say it again so everyone can hear. Refuse to repeat the response. Ask the person to repeat as often as necessary.
- Accept the response and do not say anything. By nonverbal behavior, indicate openness to additional comments.
- Instead of repeating, say "Anything else?" or "Any other comments?"

In group discussion, students should be talking to each other, not just to the facilitator. By making the group members responsible for initiating the ideas and questions that are to carry the discussion, the facilitator can get away from directing the traffic of interaction.

Restricting Words. Words are often used that inadvertently restrict or distort the openness of discussion, for example,

- What "important" things did the film show us?

Now the person must guess what the facilitator thinks is important. The facilitator could just as well have asked:

- What did the film show you?

However, a restricting question may have an ordering effect on a discussion, especially if students have been giving poorly considered or trivial answers. A restricting word produces a restraint that may be desirable or undesirable, according to the circumstances.

To help avoid restricting words, write down ahead of time the major questions that you intend to ask during the discussion. This does two things. First, when the question is on paper, it can be analyzed ahead of time to weed out restricting words. Second, if the question is written down, there is less chance to "ad lib" and throw in extra words that may be confusing.

Leading Questions. Leading questions suggest how the facilitator wants the group to answer.

- It would be a good idea to pave that street, wouldn't it?
- Of course, the best way to do it is to walk to work, right?

Such questions can be used effectively to direct discussion toward a desired end point or to challenge students to think. In certain groups, leading questions can be used to stimulate discussion by forcing an answer that is obviously incorrect or uncertain. Members of the group can then respond to the absurdity of the question. Such leading questions must obviously be used sparingly and with caution.

On the other hand, leading questions may restrict an open discussion because the group has to decide what to answer in order to gain acceptance from the facilitator. In addition, the facilitator may have difficulty in judging the students' understanding of the information received because answers have already been suggested.

Loaded Questions. A loaded question traps a person. The student is caught no matter how the question is answered.

- Have you stopped throwing chalk?
- "Yes, I have" or "No, I haven't."

No matter what, the student must admit to throwing the chalk at least once.

- When are you going to stop being so stubborn?

These are the classical "have you stopped beating your wife?" questions.

This type of question can be used to cause members of the group to think. These are trick questions that are best used by the experienced facilitator. One must be cautious in their use since they, too, can restrict discussion.

Multiple Questions. In the enthusiasm to emphasize the importance of a question, the facilitator often elaborates with additional questions and ends up by switching the focus from the original, intended question. For example,

- What was the substance that showed the most violent reaction?
- Which reaction produced the most heat?

These multiple questions often leave group members confused. This is usually caused by not writing down ahead of time the questions to be asked.

Wait Time (Time to Think)

The most important element in any discussion is to allow time to think. Many people find it extremely difficult to tolerate silence. Keep in mind that thinking processes are sometimes slow and painful. Wait for a response. When a prolonged silence ensues, support the person by saying something like

- Would you like to keep working on your problem or would you like someone else to help you?

If the student decides to resolve the problem alone, be sure to call for a response when the solution is finally reached. The same procedure may be followed when a student says:

- I know what I want to say, but I can't say it.

Research carried out by Mary Budd Rowe and others over the last decade has clearly shown the effects on student and teacher behaviors in science classrooms where students are allowed time to think. Rowe found that the average amount of silent time a teacher allowed to pass between question and response (which has now become known as wait time) was just one second. Further, the average wait time between student response and teacher response or another question

was only .9 second. It has been found that the average inquiry science teacher asked from 3 to 5 questions each minute, or over 200 questions in one class period. This is inquisition, not inquiry.

Rowe found that increasing wait time to three seconds had the following significant effects on student behaviors:

- The duration of student responses increased.
- The number of spontaneous amending comments increased.
- The number of "no" and "I don't know" responses decreased.
- The number of tangential or inflected responses decreased.
- The number of speculative responses increased.
- The amount of student-student comparing of data increased.
- Students made more inferences from data.
- The frequency of questions raised by students increased.
- The number of experiments proposed by students increased.
- The frequency of responses by students rated lower achievers by their teachers increased.

Increases in wait time also resulted in important changes in the following teacher behaviors:

- Teachers became more flexible in their responses to students. They were more willing to accept diverse answers.
- Teachers' questioning strategies became more manageable. While the number of questions decreased, the variety and quality increased.
- Teachers raised their expectations for students who had been previously described as lower achievers.

If a question is asked of students in the group and they just sit and look blank, relax. Wait and say nothing. People usually need time to think. If someone says "I don't understand," repeat the question or rephrase it for clarification, being careful not to change the focus. As Mary Budd Rowe says: "Inquisition is something teachers do to students. Inquiry is something teachers and students may do together." Allow time to think.

Summary

Teachers must play many different roles in the classroom. One of the most important of these roles is that of discussion facilitator. In this role, teachers must understand and practice skills characteristic of good leadership in order to establish and maintain group involvement and interaction. Different facilitator roles require different kinds of discussion techniques and require teachers to act in different ways. Facilitating discussion can be learned and therefore can be taught to students. If teachers become conscious of what they are doing to facilitate discussion, they will be better able help students develop good discussion skills.

Remember to ask yourself the following things while shaping an inquiry discussion:

- Are my questions phrased simply and directly?
- Am I avoiding compound or multiple questions?
- Am I using an adequate mix of recall, processing, and applying questions?
- Are my questions extending and lifting the discussion?
- Are my focusing questions clarifying particular aspects of the investigation?
- Do some of my questions build cognitive conflict?
- Am I asking some comparative questions?
- Am I calling on individuals after rather than before I pose questions?
- Am I allowing at least 3–5 seconds for a student's response?
- Am I accepting students' responses without prejudgment or editing?
- Am I asking for examples of student ideas?
- Are my grouping techniques conducive to good discussion?

DEFINITIONS OF LEARNING

Education is in the midst of a change commonly called school reform. However, different perspectives on what reform means result in miscommunication, confusion, and in many cases, lack of direction. To some, reform means "school improvement"; to others it means fundamental "restructuring." Educators and community members use these words in different contexts, with different meanings, and for different reasons.

Education has been operating under an industrial model. Schools are viewed as assembly lines. Objectives set by persons outside the learner's environment define the end product. The learner is the recipient; the teacher, the information giver; the principal, the manager who oversees the workers and facilities in the learning process. Learning is seen as the accumulation of information. Ample evidence and hundreds of national and state reports indicate that such a model of education is failing to prepare students for a world that is becoming more globally interdependent, technologically complicated, and information intensive. The industrial model is clearly inadequate for today's students.

"School improvement" suggests incremental changes in curriculum, instruction, assessment, and so on, which might be characterized as minor tinkering or fine tuning of parts of the educational system. "School restructuring," on the other hand, suggests major changes in schools and how they are operated including decentralization, school/community-based management, curriculum change, and fundamental changes in instructional strategies. The main difference seems to be a matter of vision. Restructuring requires a strong vision of learning, curriculum, instruction, assessment, and organization of the school. Once developed, this strong vision can guide comprehensive changes in schools. Restructuring, then, is comprehensive change designed to promote meaningful learning for all students.

Multiple Definitions of Learning

At the heart of restructuring is the question, "What constitutes learning?" The "new" visions of learning are not really new. Recent research has enriched and explicated the historical roots of early philosophers, including Socrates, Dewey, Piaget, and Vygotsky, who share a rich vision of learning focused on the learner and a view of unlimited potential for what children can learn. New terms have been invented, such as meaningful learning, problem-situated learning, reflective education, and cognitive apprenticeship, to describe the essence of successful learning as being internal to the individual. The learner must work hard to connect new information to prior knowledge and to construct mental models and explanations. The contexts for learning are now viewed in expanded ways that provide for collaboration, diversification, variety of resources, and multiple opportunities for learning.

Three perspectives seem to dominate the recent research into the nature of learning: philosophical, cognitive, and cultural. Successful and meaningful learning takes place when teachers and students are aware of all three dimensions of learning.

Philosophical Views of Learning

Philosophers stress two kinds of thinking—critical and creative. Critical thinking includes developing criteria for making judgments, developing the disposition to challenge and defend the foundations of beliefs and judgments, and verifying the validity of knowledge. Creative thinking includes looking at an issue from an unusual perspective and redefining a problem in a new or unusual way. The focus is on learners and how they identify their underlying assumptions, analyze them, and check them against their own experiences, their surroundings, and others' knowledge. This view of learning stresses a community of inquiry where students expect each other to be thoughtful and reflective, listen to each other to support opinions, assist each other in drawing out the implications of what has been said, identify and challenge assumptions of arguments, and question one another's definitions. Philosophers want learners to have a passion for reflec-

tion and inquiry pervading their thoughts and their lives

Philosophers want learners to have a passion for reflection and inquiry pervading their thoughts and their lives.

Philosophers argue that developing such habits of thought is essential to maintaining a democratic society. Without such critical thinking we are prisoners of our own beliefs, unable to judge right from wrong or to make informed decisions.

Attempts to incorporate this view of learning into the curriculum are under way in several areas. Matthew Lipman's *Philosophy for Children* is one example. This program for elementary school students engages them in philosophical thinking requiring observation, classification, challenging premises, and making judgments about oneself and the world. Students draw on their own experiences and compare and contrast them to situational problems presented in the program. Lipman has established that even young children can attain philosophical understanding that the world is ambiguous, mysterious, and is a constant source of wonderment and learning.

Another example is the *Developmental Approaches in Science and Health* (DASH) program under development at the Curriculum Research & Development Group of the University of Hawaii. A typical DASH activity engages kindergarten students in collecting living and nonliving things. Back in the classroom, students group their collections and discover that not all things fit nicely into categories. New categories must be invented, such as "once living." Classroom discussion engages students in analyzing the meaning of "living" and "nonliving," only to discover that such definitions are ambiguous even to adults. New concepts are entered into the class "Working Dictionary," where definition and understanding evolve with experience. Applications of new understandings are extended beyond the activity to the class, the school, and the home.

Cognitive Views of Learning

Several related fields contributing to a cognitive view of learning include cognitive psychology, educational psychology, psycholinguistics, and pedagogy—the study of teaching. This view, like the philosophical view, emphasizes higher-order thinking skills (including critical and creative thinking), metacognition (thinking about thinking), collaborative learning, and inquiry. Cognitive researchers help us understand how learners acquire and use knowledge and what conditions produce optimal learning.

Cognitive research has reaffirmed our own intuitions about learning. Learning requires more than memorizing and regurgitating facts. According to this view, the essence of learning is making connections, linking new information to prior knowledge, and testing its application in real-world situations. Learning in school must relate tasks and experiences that students engage in outside school. Further, learning takes place in a social context; dialogue is critical. Therefore, this view of learning also emphasizes collaboration and self-questioning. Learning consistent with the cognitive view engages students in self-regulated learning, that is, in setting their own goals, monitoring their own progress, assessing what they have learned, and determining the next steps for learning.

Cognitive perspectives also stress the importance of content knowledge. Successful learners use content knowledge to interpret new situations; to identify, define, and solve problems; to make judgments; to classify information; and to reason. They organize what they know by patterns and principles. They are aware when new knowledge conflicts with prior knowledge, when cognitive conflict occurs. Learning takes place through conceptual change and resolution of cognitive conflict. Such knowledge is accessible and useful in new applications.

In the DASH program this perspective is exemplified in students' daily activities. They begin each day recording morning observations on the DASH Learning Calendar. Each activity begins with what students already know and then engages them in hands-on activities in which small groups working together decide how to go about the tasks that will connect new learning to prior knowledge. Students use common materials and objects such as water, bubbles, paper plates, and plastic bags rather than unfamiliar equipment.

. . . the essence of learning is making connections, linking new information to prior knowledge, and testing its application in real-world situations.

The "Working Dictionary," mentioned above, becomes a repository of what students know about a concept at any given time, but their definitions change constantly as new experiences enlarge their understanding. Each day ends with a discussion that essentially focuses on the question, "What have I learned today that I did not know before?" Students record the results of these discussions on the DASH Learning Calendar in pictorial symbols. Discussing and recording what they learn is essential. Learning is further enhanced through home activities that students engage in with family members, expanding what they have learned and connecting it to out-of-school contexts. An approach which enables learners to develop a repertoire of learning strategies such as elaborating and summarizing, critical and creative thinking, decision

making, and self-assessment of learning.

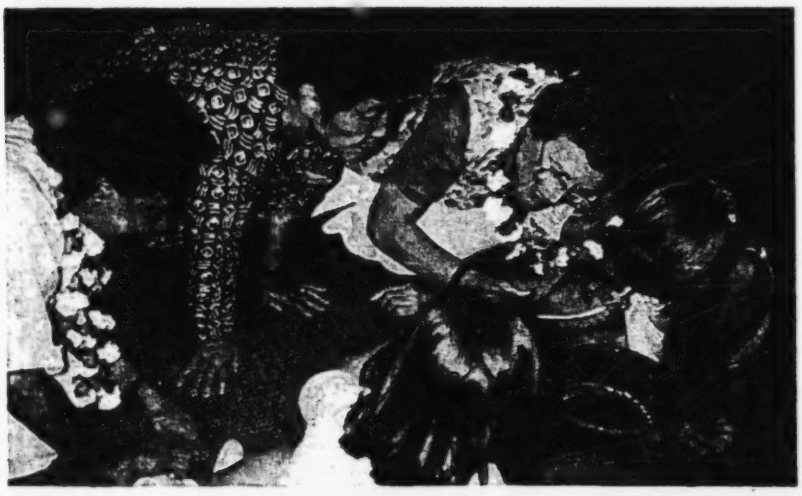
Cultural Views of Learning

Cultural views of learning expand and extend the insights gained from philosophy and cognitive research by focusing on differences in experiences that students bring to a learning situation. Some basic premises underlie this view of learning. Among them are the convictions that all students can learn, that they learn best when new knowledge is connected to and built on real experiences and meanings from their own lives, and that cognition is modifiable. Learning in this view is an active process of inquiry, and the construction of meaning must begin with what the learner already knows.

The cultural view emphasizes that we cannot ignore the child's prior knowledge. It forms the cornerstone upon which to build learning.

Language and culture play critical roles in learning. Too often schools do not legitimize the knowledge or experiences that minority children bring to school. Schools too often label such children as failures because their backgrounds, language, and culture have been inadequate to prepare them for learning in school. Old models of learning ignored multicultural differences. The cultural view emphasizes that we cannot ignore the child's prior knowledge. It forms the cornerstone upon which to build learning. Every culture brings habits of thought, resources, and contexts that have built into them vehicles that promote learning. It is therefore crucial to link new learnings to the culture and experiences of students, to make the contributions of culture a meaningful part of classroom dialogue, and to create experiences in the classroom that all students can engage in and learn from.

In science, this view would mean using common materials and technologies. DASH, for example, uses bicycles, buildings, bathrooms, plumbing, swings, bubbles, clothing, classroom animals, and so on, as entry points for children to learn about science, health, and technology. As discussed above, collaboration, inquiry, written and oral language development are integral to learning in DASH. In such contexts, multicultural differences enhance, expand, and enrich learning for all students in the classroom. DASH emphasizes continuous dialogue about the phenomena under study not to only draw out and connect to the prior experiences of multicultural learners, but also to help these learners develop the language that will help them succeed in school.



Characteristics of Successful Learners

These three views of learning share some observations about successful learners and meaningful learning.

Knowledge. Successful learners have a considerable amount of content knowledge and can use it with fluency and authority. They constantly evaluate the quality of the knowledge they receive and produce. They are reflective and curious. They are aware of their own strengths and needs as well as others'. They can define and solve problems critically and creatively.

Self-Regulation. Successful learners consciously engage in inquiry. They are motivated and self-confident. They persevere in the face of difficulty and view the world as full of opportunity. They are aware of what they know, as well as their limitations, and constantly engage in self-analysis. In problem situations they are able to identify what they already know, what they don't know, and what strategies are likely to result in learning.

Strategies. Successful learners organize what they know and construct mental models or principles against which they can compare new knowledge. They constantly compare new knowledge to what they already know and adjust accordingly. They know a number of strategies for learning various subjects, for problem solving and decision making, and for thinking creatively.

Communication. Successful learners know that much of their success and learning depends upon interaction with others. These interpersonal skills are particularly important in multicultural contexts. Learning involves knowing how to identify the strengths and misconceptions of others, how to be supportive, and how

to communicate what one knows to others. Successful learners value sharing experiences in multicultural settings because it enriches their lives.

Implications for School Reform

These new definitions of learning emphasize collaboration, inquiry, and thinking. Students do not learn by engaging in meaningless tasks that are fragmented and out of context. Real learning takes place through engagement in authentic tasks, through interaction with others, and through sustained thinking. Meaningful learning involves the interaction of the learner, the content, the context, and the teacher, as well as the social and cultural experience of the learner. New conceptions of learning cannot be implemented without attention to the content of the curriculum or the quality of instruction.

Of particular importance are the implications for so-called low-achieving students. Our increasing knowledge of the optimal conditions for learning for these students suggests that they cannot be segregated and deprived access to a meaningful education. Such students perhaps more than any must be provided with authentic tasks with real-world applications. Teachers and school personnel in general must share high expectations for such students. Ample opportunities must be provided for all students to interact with teachers and peers who are themselves good thinkers and good learners. Such opportunities rarely occur in homogeneously grouped, low-achieving classes.

Schools as presently organized restrict access to educational opportunity largely on the basis of cultural background. Tracking in low-level classes virtually excludes students from high-level content, instruction, or expectations. If schools were to restructure to base curriculum and instruction on the language and culture of all children, such exclusion would end.

Schools undergoing restructuring begin to reflect new patterns of interaction among teachers, administrators, students, parents, and community. These interactions focus on the collective vision of meaningful learning as it is reflected in the curriculum, in instruction, and school structures and emphases. In such schools teachers work with other teachers to deliver an interdisciplinary curriculum and share strategies that promote collaboration in the classroom. Students assist other students in learning. Administrators and teachers collaborate on how to apply new teaching and learning research in the ongoing renewal of their school.

These new views of learning also have political implications. The industrial model of education assumed that only the brightest would be successful learners and that few public schools could provide optimal learning for all students. Now research is helping us to identify the characteristics of successful learners. We are beginning to believe that performance of all learners can be significantly modified and that schools can make a difference. Collectively, the recent research on learning suggests that schools should focus on good academic skills, higher-order thinking, self-directed learning, collaboration, and problem solving from kindergarten through graduation, that access to quality education should be provided to all students in school, not just the academically brightest, and that the way to begin is through authentic learning tasks, teamwork, and collaboration in classrooms and schools.

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A MODEL FOR ORGANIZING A CURRICULUM WITH TECHNOLOGICAL CONTENT

The designers and developers of DASH have made a series of assumptions about the role of technology in society and its impact on science as well as on the humanities and the biophysical environment. They have made other assumptions about the cognitive characteristics of students as they relate to the social and production communities.

Assumptions About the Social and Production Communities

1. Technology in the sense of crafting things and providing services was practiced long before the advent of either the biophysical or social sciences.
2. The functions of the earliest technologies—finding food, water, and shelter—still consume much of the effort of modern technology.
3. Historically, activity in both social and production humanities preceded the emergence of science but followed long after the earliest technologies.
4. The functions of practitioners of the humanities have changed only in detail over time. (Painters, musicians, actors, philosophers, and historians of 3,000 years ago would find their modern counterparts still doing the kinds of things that filled their days.)
5. Historically, the sciences—both social and biophysical—have tended to follow the lead of technology in identifying targets of interest; this tendency continues today.
6. Because science has emerged from technology, people need to understand technology if they are to understand science.
7. Technology, in all its senses, has higher impact and visibility in the lives of students than science has; therefore technology is more readily available for reinforcing the lessons of the school than science is.
8. Activity in the production humanities (graphic arts, epics and chants, literature, and the like) has historically provided tools that are valuable in technology.
9. Skills and crafts from the production humanities should be taught in part for their contribution to technology and science.
10. Because the social humanities keep the historical record and act as the conscience of the social and production communities, study of the social humanities is essential to a full understanding of science and technology.

Assumptions About the Cognitive Development of Children

11. The cognitive development of children generally follows the historical sequence of development of concepts, skills, theory, and systems structures as they have evolved in the social and production communities. (In general, the most accessible, transparent, and basic concepts and processes were invented first; these same concepts and processes are usually the most readily learned by beginners.)
12. The introduction of concepts, skills, theories, and systems should follow the logic of historical development of the social and production communities.
13. In any heterogeneous classroom, students will develop concepts, skills, theories, and systems structures at different rates.
14. Instruction must be redundant, spiraling through content to provide multiple exposure for students needing multiple reinforcement. (Technological processes and devices are inherently redundant, and new structures, processes, and techniques are built on top of old ones.)
15. Historically, social and production communities have used a multiplicity of modes of communication, including kinesthetic, linguistic, pictorial, musical, and mathematical.
16. The modes of communication used with students should include the kinesthetic, linguistic, pictorial, musical, and mathematical in parallel with the practices of the social and production communities. (Work on multiple intelligences suggests that each mode taps a different reservoir of capacities. Using a multiplicity of communication modes increases the probability of tapping some set of capacities that will help each student learn the concepts and processes.)
17. In any heterogeneous classroom, students will show different capacities to understand and respond to different modes of communication.
18. The unique mix of communication capacities of children should be noted and used in instruction.

Assumptions About the Intent of Curriculum

19. Instruction should emphasize the fullest possible understanding of the conceptual structures, values, methodologies, functions, and histories of the social and production communities, their interconnectiveness, and their impact on the milieu.
20. Instruction should emphasize matters that have high potential for helping students gain independence and control over their own environments.
21. Instruction should strike a balance between theory and application to increase the potential for rationality in action.
22. In the social and production communities, conceptual knowl-

edge and skills are normally learned by apprenticeship in doing the tasks characteristic of the communities; therefore students should engage in the tasks done by members of the communities.

Curricular Assumptions and Content Selection

With its emphasis on science, health, and technology firmly in mind, the DASH staff began exploring the assumption that history is a practical guide to selecting content and organizing curriculum.

A sustained look at the history of human evolution through the lens of health, science, and technology makes it apparent that satisfying basic biological needs occupied much of the time of our ancestors; satisfying those needs still consumes much of our time today. Our need for air is continuous. Our need for sleep uses 6 to 8 hours a day. Meeting our need for food—growing or buying it, preparing it, and eating it—takes up to 3 hours. We are exercising, one way or another, during most of our waking day. In fact, it is only because we can do a multiplicity of things at the same time that we can escape concentrating solely on meeting our biological needs.

Archaeology reveals that technologies first emerged to augment efforts to satisfy basic needs. Some 2 million years ago, implement-making improved the capacity to cut up food and drive away predators. Later, fire came under control, and clothing and shelters were invented, extending the hours of waking, the season of wandering, and the range of human habitation. Evidence of the humanistic impulse emerges in artifacts 100,000 years old, but it was not until the last 10,000 years that artisan-specialists appeared, and until the last 2,500 years that the beginnings of systematic science can be traced. During this time art, religion, and science focused heavily on the practical dimensions of living—the making of decorous but utilitarian items; the inspired prediction of the seasons, eclipses, and conjunctions of the stars; and the functional observation of plants, animals, minerals, and other resources in the environment.

Since satisfying basic biological needs shaped the earliest technologies, humanities, and sciences—and is still is the first concern of society—basic biological needs have formed the content focus of DASH in grades K–3.

Communities and Content Selection

To determine which communities to reflect in DASH, the staff again consulted history and the model of the communities. To simplify the process, the DASH staff used a truncated version of the global technology model, collapsing the six communities into three groups: technology, science, and humanities. Next, the staff constructed a matrix to identify the contributions of technology, science, and the humanities in premodern times to satisfying basic biological needs. Figure 1 is an example of DASH's analysis.

As DASH staff attempted to validate the approach by using basic biological needs as a search probe with the model, the communities normally represented in a health program emerged naturally. Health as a school topic is a hybrid deriving content from medicine, nutrition, psychology, physical education, sanitation, and so on.

In addition, language, the plastic and graphic arts, song, and dance provide instrumental skills needed for communication. Chant, song, and dance are mnemonic tools in many cultures—and most useful in lower elementary education. Ethics provides the rules of social interaction. An unexpected and informative outcome of the search was recognition of the need to represent a wide selection of basic technologies rarely included in the curriculum.

Integrated, Global View of Technology

DASH assumptions call for the understanding of technology, science, and the humanities to issue from doing tasks representative of the communities. Therefore it is in the selection of tasks that integration emerges. Here the integrative nature of technology becomes most apparent. This can best be seen in an example.

Gardening is an ongoing thread in DASH, starting in kindergarten. Gardening was selected because it is a part of farming accessible to children, one they can often do independently. Over a span of years, gardening calls for studying water, transporting water, learning the water needs of plants, studying the soil, understanding wet and dry soils and soil quality, studying fertilizer, learning which chemicals are needed to support plants, deciding whether to use commercial fertilizers or compost, studying plants, learning the developmental cycle of plants and the parts of plants, participating in group planning, sharing responsibility, learning the economics of gardening and the value of crops, calculating the cost of growing and fertilizing a crop, learning the nutrient content of vegetables and fruits, considering the aesthetics of gardening and the beauty of plants, sensing the satisfaction of keeping a clean, neat garden, and handling the problems of pesticides and waste.

In the context of gardening are found the natural connections that lead to studies of other technologies—problems solved with science and problems solved with the tools of the humanities. These activities are organized according to DASH assumptions.

The outline for the upper elementary grades is a continuance at the K–3 outline. It emerges out of higher order biological needs and embraces content flowing out of the empirical, social, earth, and biophysical sciences.

TECHNOLOGICAL AND SCIENCE AREAS FOR CONTENT SELECTION IN THE LOWER ELEMENTARY GRADES

BIOLOGICAL NEEDS	TECHNOLOGY	SCIENCE
AIR	VENTILATION	DESCRIPTIVE METEOROLOGY
WATER	PLUMBING HYDROLOGY	
FOOD	HUNTING, GATHERING, HERDING, FARMING	NATURAL HISTORY
SLEEP	SHELTER CRAFTS	
ELIMINATION	SANITATION	
REPRODUCTION	ANIMAL BREEDING	
DISEASE-INJURY PROTECTION	MEDICINE	
THERMAL PROTECTION	TAILORING SHOEMAKING	
EXERCISE	SPORTS	DESCRIPTIVE ASTRONOMY
MOBILITY	WAYFARING, TRANSPORTATION	
INTERPERSONAL BONDING	FAMILY, CLAN, COMMUNITY	
LEARNING	APPRENTICESHIP SCHOOLING	
COMMUNICATING	LANGUAGE GRAPHICS	
CURIOSITY	ALL TECHNOLOGIES	
AESTHETIC BALANCE	MUSIC, DRAMA PAINTING, SCULPTURE WRITING	

TECHNOLOGICAL AND SCIENCE AREAS FOR CONTENT SELECTION IN THE UPPER ELEMENTARY GRADES

BIOLOGICAL NEEDS	TECHNOLOGY	SCIENCE
SOCIAL BONDING	MENTAL HEALTH SYSTEMS	PSYCHOLOGY SOCIOLOGY
LEARNING	EDUCATION SYSTEMS	EDUCATION
COMMUNICATING	COMMUNICATION SYSTEMS	INFORMATION SCIENCE
CONTROL OF SELF AND OTHERS	GOVERNMENTAL SYSTEMS	POLITICAL SCIENCE ETHICS
ACQUISITIVENESS	MERCHANDIZING BANKING SYSTEMS	ECONOMICS
CURIOSITY	ALL TECHNOLOGIES	ASTRONOMY BIOLOGY CHEMISTRY EARTH SCIENCES PHYSICS
AESTHETIC BALANCE	MUSIC, DRAMA PAINTING, SCULPTURE WRITING	AESTHETICS HISTORY CRITICISM

MULTIDIMENSIONAL ASSESSMENT

In the last two decades new definitions of learning have emerged that are based on cognitive, philosophical, and multicultural research. These perspectives suggest that *meaningful learning occurs when a learner has a knowledge base that can be used with fluency to make sense of the world, solve problems, and make decisions. Learners need to be self-determined, feel capable, and continually strive to acquire and use the tools they have to learn. They need to be strategic learners who have a repertoire of effective strategies for their own learning. Finally, they need to be empathic learners who view themselves and the world from perspectives other than their own* (Kulieke et al, 1990).

These new perspectives call for rethinking the roles of students and teachers in the learning process. It is primarily through dialogue and interaction that students become knowledgeable, self-regulating, strategic, and empathic. This calls for collaboration in classrooms among students and between students and teacher. The collaborative classroom is characterized by shared knowledge, shared authority, teachers as facilitators, and heterogeneous groupings of students.

The essence of learning is making connections, linking new information to prior knowledge, and testing its application in real-world situations. Learning in school must be related to tasks and experiences that students engage in outside school.

Such changes in our definitions of learning and teaching and in the contexts of classrooms also call for changes in assessment practices. A new vision of assessment is evolving. It is not yet complete, but what is clear is that the traditional ways of assessing student learning are inadequate to our new ideas about the nature of intelligence, ways of knowing, and the utility of knowledge.

. . . changes in our definitions of learning and teaching and in the contexts of classrooms dictate changes in assessment practices.

Multiple Intelligences

One of the major influences on our current views of learning has been the theory of multiple intelligences developed by Howard Gardner, a cognitive psychologist at Harvard University.

Gardner proposes that there are many kinds of knowledges, abilities, or what he calls "intelligences." He identifies the following specifically.

- **Linguistic**—the gift of language exemplified by T.S. Eliot; sensitivity to the sounds, rhythms, and meanings of words; sensitivity to the different functions of language.
- **Logical-mathematical**—exemplified in the "scientific thinking" of Nobel laureate Barbara McClintock; the ability to discern logical or numerical patterns and to handle complex reasoning.
- **Bodily-kinesthetic**—the control of body movement shown by Larry Bird; the ability to handle objects skillfully.
- **Spatial**—the gift of being able to handle spatial relationships and multidimensional space; to be able to visualize mental pictures in three dimensions like Mau Pialug or Nainoa Thompson who navigate the Pacific without the use of instruments.
- **Musical**—the ability to produce and appreciate rhythm, pitch, and timbre; appreciation of the forms of musical expression, a Yehudi Menuhin.
- **Interpersonal**—capacities to discern and respond appropriately to the moods, temperaments, motivations, and desires of other people exemplified in the relationship between Anne Sullivan and Helen Keller.
- **Intrapersonal**—knowledge of one's own feelings, strengths,

weaknesses, desires, and the ability to draw upon this knowledge to guide behavior.

Gardner argues that traditional education develops only two of the seven intelligences—linguistic and logical-mathematical—at the expense of the other five. Our "IQ-style thinking," in which some people are considered to be smart and others dumb, is entrenched in our language. We have "quick tests" of IQ, the SAT and many others that suggest that if your score is high you're smart, but if your score is low you're not.

Gardner challenges the single intelligence view by defining intelligence as the ability to solve problems or fashion products valued in at least one cultural setting. He believes that the human mind has developed over time to do a wide variety of tasks. Mind is not one thing, but a set of intelligences keyed to different kinds of tasks. Gardner also believes that normal people have all of these intelligences to different degrees.

His theory is in direct contrast to Piaget, who believed that if an individual were at a particular developmental level, they were at that level in all tasks. This is simply not the case. If it were, there would be no explanation for a child prodigy in any task, says Gardner.

Gardner argues that since individuals have different degrees of intelligences, the "uniform school" cannot work. He suggests that we must provide choices and establish individual-centered schools. In such schools everybody takes some of the same courses, but a lot of attention is paid to developing individual intelligences to the fullest.

Major Shifts in Assessment

Assessment needs to be "intelligence-fair." We generally believe that instructional materials should be rich, fun, and motivating. Tests should be like that too. Gardner says tests should

- not be extremely subjective
- have total face validity; that is, they should obviously measure what they intend to test for
- rely on multiple measures of knowing, that is, provide multiple ways for students to demonstrate what they know or can do
- show strengths as well as weaknesses. Students should not be penalized for what they reveal they don't know. Such information should be used to guide instruction,
- be appropriate to the domain and subject.

Assessment builds on student strengths as learners, is ongoing and continuous as opposed to isolated and time-specific.

Instruments used to test students need to be sensitive to the developmental level of the individuals as well as sensitive to individual differences. Results of testing should be used to help individuals, not to rank them in comparison to their fellow students. Projects, according to Gardner, are much better than tests because they require synthesis and application on the part of the student; they are more user-friendly; they are more intelligence-fair; and they are much closer to the kinds of evaluations used in real life outside school. This is not generally true of standardized, formalized tests.

From Testing to Multiple Assessment

Such changing views of intelligence, learning, and teaching are leading educators to explore shifts of emphases in assessing learning. With an expanded concept of intelligence and learning it is increasingly important to know that the traditional paper-and-pencil test is only one way to collect data on student learning. The broader concept of assessment includes such tests, but also includes rating scales, observations of student performance, critiques of student projects, interviews, and reviews of student's background and previous performances. Assessment builds on student strengths as learners, is ongoing and continuous as opposed to isolated and time-specific.

New strategies such as portfolios and day-to-day assessments are beginning to be widely used. A portfolio consists of student exhibitions that demonstrate mastery of skills of inquiry and expression. Students "show off" what they know and what they can do. Exhibitions require

reading, writing, questioning, speaking, and listening. They are the culmination of a series of performances in a subject area.

Exhibitions focus on student abilities to use and display knowledge. They are authentic measures of learning and the ability to engage in inquiry. They require skillful expression and can motivate and engage students meaningfully in their own learning. Assessment becomes another way of learning and developing deeper understanding.

Day-to-day assessment performances can also be authentic and engaging. They become an integral part of the instructional cycle and feedback. Dialogue between teacher and student is intended to help the student assess strengths and weaknesses, identify what needs to be learned, and help push the student to the next level of skill in performance.

Toward Multidimensional Assessment

Gardner describes two approaches to student assessment: standard formalized testing and apprenticeships. He thinks that education has veered too far toward standardized testing which continues to assess only certain dimensions of learning while ignoring the apprenticeship approach. *Why do we spend so much time taking tests in school? When we leave school we never take such tests again, while assessment on the job takes place all the time.*

In the apprenticeship approach, assessment is based on the broader concept of multiple intelligences. Not only are linguistic and logical-mathematical intelligences assessed, but so, too, are the spatial, musical, kinesthetic, interpersonal, and intrapersonal. This means assessing students' learning, skills, and knowledge as they are applied in day-to-day and culturally diverse contexts. It is broad-based, relevant to life, process-oriented, and based on multiple measures providing thick, rich pictures of student learning.

Kuklieke et al. (1990) portray some of the shifts in assessment as shown in Figure 1. These include a movement from decontextualized, atomistic tests to authentic, contextualized tasks such as performances and projects; from single measures to multiple measures of student learning; from simple to complex dimensions of intelligence and learning.

Some Practical Examples

Progress is being made in developing multiple ways to assess student progress. Use of portfolios, exhibitions, performance assessments, and projects has already been mentioned. Still other ways include using videotape portfolios that document the learner's interests and accomplishments from initial interview through work during the year to final performance level.

Student journals with weekly entries about projects, progress, needs, and so on, have also proven valuable for both student self-assessment and teacher-student interaction. Creating an atmosphere in which students can reflect on what they know and what they are unsure of and providing time for reflective writing allow students to reveal the progress of their learning to themselves and to their teachers.

In the *Developmental Approaches in Science and Health* (DASH) program under development at the Curriculum Research & Development Group of the University of Hawaii, we have been researching the use of alternative assessment strategies. Some of these, such as the portfolios and performance assessments, are an integral part of DASH. Among the more innovative strategies introduced in DASH are the Learning Calendar, Working Dictionary, Wonder and Discover Book, and the Connections Book.

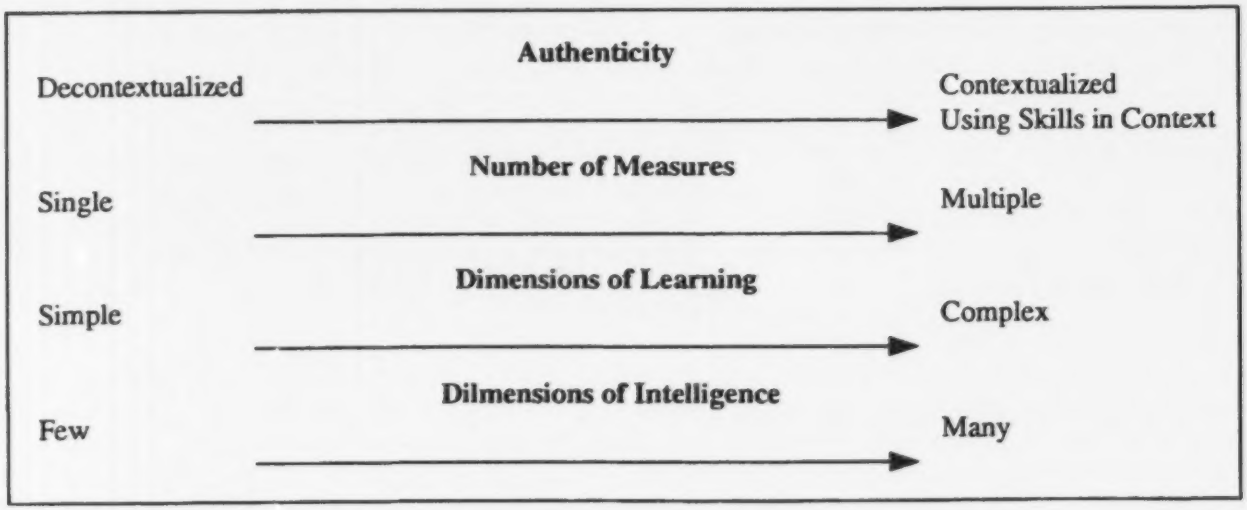
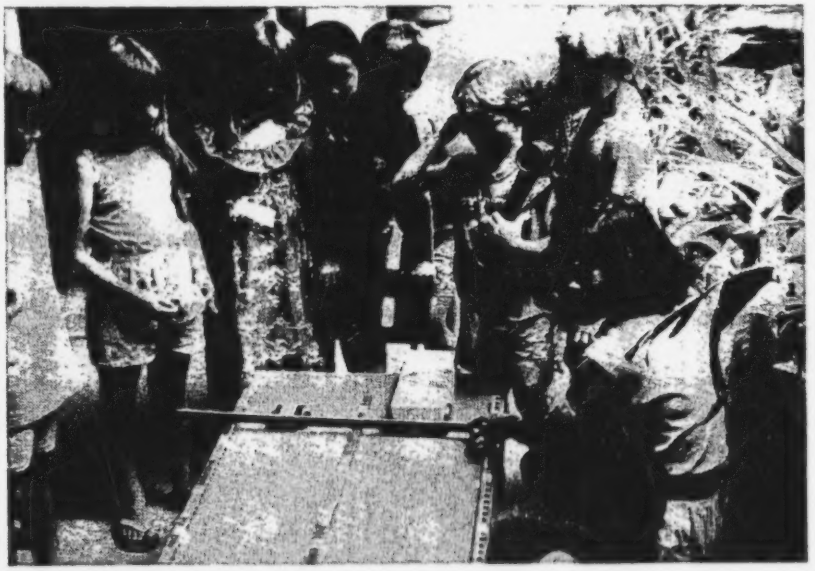


Figure 1. Shifts in types of assessment

Students begin each morning recording date, temperature, observations of weather, moon, sun, and other common aspects of their environment on the Learning Calendar, a continuous roll of large-sized paper. Each day ends with a discussion that essentially focuses on the question "What did I learn today that I did not know before?" Results of these discussions are recorded on the Learning Calendar in pictorial symbols and words by students. Discussing, languaging, and recording what is learned is essential, but it also reveals to the teacher what each child knows and can do with that knowledge. The calendar is periodically unrolled, allowing students to examine their own progress in learning. Fundamental to the DASH Learning Calendar are the connections between what I learned today, what I learned yesterday, and what I want to learn tomorrow.



The Working Dictionary is used to record definitions of concepts students are learning in a big-book format. Only student definitions are recorded, not textbook definitions. This encourages students to verbalize what they know in front of others, one way of further developing understanding. The Working Dictionary becomes a repository of what is known at any given time about a concept, but definitions are constantly changing as new experiences enable students to expand on what they know. The openness of the dictionary approach enables teachers and students alike to gain a clearer picture of what they know.

Extending beyond the lessons in class, the Connections Book, also in big-book format, allows students to record ideas they have about how what they are learning in school connects or relates to events outside school. Teacher-led, open-ended discussion allows students to express ideas they have about what they know from both in and out of school. This provides a wealth of multicultural dimensions to school work and enhances everyone's knowledge, especially the teacher's. The teacher now has a way of examining and recording how student knowledge is developing and especially students' ability to use that knowledge.

Class discussions centered on the Learning Calendar, the Working Dictionary, and the Connections Book often raise questions that have not been answered and were not anticipated by the teacher. These questions are to be cherished. They are authentic questions that students have about what they are learning and the world around them. In traditional classrooms such questions can be ignored. In DASH, they are recorded and proudly labeled with the student's name in the Wonder and Discover Book. Many are explored in later activities. Some become so engaging that students involve family members in trying to find answers. Some the teacher helps with. Still others may be left unanswered. But the Wonder and Discover Book provides a way of assessing what kinds of questions students have about their learning.

Focus on the intrapersonal aspects of intelligence leads to other kinds of assessment—self assessment. This too is an integral part of DASH. We have successfully used a concept and skill inventory in which students record their own assessment of their understanding of concepts being taught in class. They are asked to respond to a verbal or written list of concepts or skills by checking that they do not understand, that they understand, or that they could teach someone else. This reveals otherwise unavailable assessment data to both teacher and student. Where discrepancies occur between student self-assessment and teacher observations of performance, the students are asked to teach what they know. Results so far have revealed profound insights among some students that teachers never would have imagined.

From Isolated to Integrated Assessment

As can be seen from the examples above, accompanying the move from a single test as a measure of student learning to multidimensional assessment has been a move to integrate assessment into classroom practice. Instead of viewing "the test" as an isolated event signaling the completion of instruction, the new vision is a continuous learning process in which

students orchestrate learning strategies in a dynamic flow as they move in and out of different tasks of learning and assessment. This new vision of learning requires an environment where instruction and assessment are integrated and where assessment is not considered a single event.

Why do we spend so much time taking tests in school? When we leave school we never take such tests again, while assessment on the job takes place all the time.

Valencia (1990) notes that sound assessment is anchored in authenticity—authenticity of tasks, texts, and contexts. This means assessing the understanding, integration, and application of concepts and skills in meaningful contexts. Assessment must be continuous, formative, and informative. Drafts, plans, sketches, and outlines all become important parts of the final product. Further, assessments must provide for active, collaborative reflection by both teacher and students. Students must be active participants in designing assessment tasks and be given responsibility for using assessment data to monitor and improve their own learning. These alternative assessments ask students to perform, create, produce, or do something that requires the use of higher-level, problem-solving skills. The assessment tasks themselves are meaningful instructional activities. They are relevant to real-life tasks or represent those common to a particular discipline.

Summary

Assessment, especially multidimensional assessment, is not a single event. Assessment is a dynamic part of teaching. Assessment helps teachers communicate expectations and standards of learning and performance to students. Assessment helps students gain information about what is valued, set personal academic expectations, internalize required knowledge and skills, promote their self-knowledge about performance, understand who is in control of learning, and improve their learning. We don't know how to do it all yet, but we're trying.

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A STUDY OF DEVELOPMENTAL APPROACHES IN SCIENCE AND HEALTH (DASH)

Developmental Approaches in Science and Health (DASH) is a new elementary school program in science, technology and health being developed by the Curriculum Research and Development Group (CRDG) of the University of Hawaii. The program is being field tested and localized in over 500 elementary schools in conjunction with the University of Hawaii and Eastern Washington University, Carnegie Mellon University, Shippensburg University, East Carolina University, Florida Atlantic University, the University of North Alabama, and Louisiana State University. These universities also provide teacher training and follow-up services to teachers using DASH.

Study Team

As part of the development and testing of this new kindergarten–grade 6 program, an intensive research effort grew out of discussions at the DASH national steering committee meeting in January 1991. A resolution was passed calling for the establishment of a diverse study team to examine the ways in which teachers were using DASH in their classrooms and the impact DASH was having on students and the schools. The innovative nature of the DASH program necessitated employment of a multidimensional assessment that includes both quantitative and qualitative research techniques. Subsequently, a team of 11 members was formed, each contributing a unique perspective to the collection and interpretation of data.

The team met for a three-day training on ethnographic evaluation techniques in April 1991. Team members were charged to return to their own states (Hawaii, Washington, Pennsylvania, and North Carolina) and initiate the research. A small number of classrooms were selected at each site to conduct a series of case studies on the impact of DASH on students, teachers, administrators, schools, and parents. Data were collected by members of the local research teams, working together in primary classrooms (K–3), beginning in April 1991 and continuing through January 1992. Over 400 hours of classroom observations were logged. Numerous interviews with teachers, administrators, parents and students were conducted and audio taped. Most of the observational time was videotaped. Data also were collected on student-created products and artifacts, including portfolios. Standardized test data were collected where available.

Additional meetings of the study team were held in October 1991 and January 1992 to analyze, compare, and share data. In addition, the training of the study team in the methods of data collection, interpretation, and reporting of ethnographic data continued at these two four-day meetings.

The Case Studies

The student populations studied were very diverse. In Hawaii, for example, both urban and rural schools were studied where the ethnic mix included Caucasian, Japanese, Filipino, Chinese, Korean, Hawaiian, Pacific Islanders, and mixed groups, none of which constitute a majority. The schools also included a diversity of achievement and income levels. In the State of Washington, the study was conducted in a laboratory school with heterogeneous classes representing a middle class community in the eastern part of the state. In Pennsylvania the study was conducted in economically depressed, rural, and middle class communities where ethnic and racial minorities are small in number. In North Carolina, the schools studied were in rural communities where the student population was approximately fifty percent Afro-American, and nearly fifty percent of the students' families have incomes below the federally established poverty level.

Findings

Experienced teachers using DASH have changed their attitudes and approaches toward elementary science in ways that result in increased emphasis on science and improved their focus on students' learning. DASH teachers spend more time teaching science than they have previously and they also use a richer set of strategies. They also integrate science and other subjects more effectively than they did in the past. More importantly, these teachers consistently report that DASH has given them renewed enthusiasm for teaching science.

Specifically, DASH teachers

1. Create an environment that is conducive to students' sharing and taking responsibility.
2. Enable students to understand and apply important science, health, and technology concepts through integration of ideas across content areas.
3. Enable students to understand and apply important science, health, and technology concepts through integration of new and prior knowledge and experiences.
4. Enable students to connect and apply important science, health, and technology concepts learned in school to the out-of-school environment.
5. Use effective inquiry teaching skills.
6. Demonstrate positive change of attitude toward teaching science.

These case studies also show that, during DASH activities, students consistently demonstrate an unusually high proportion of engaged learning

time, even in classes where science activities extend for over an hour. In addition, students demonstrate knowledge of important concepts and skills in science, health, and technology. The data show that students connect and apply what they learn in school to their lives outside of school. Students in DASH classrooms also show increased curiosity and proficiency in inquiry skills including questioning, observation, measurement, and use of instruments and information sources to acquire data. Observations of students in classrooms and teacher reports confirm that students consistently take and share responsibility for their own learning and for classroom operations. The evidence suggests that students who are in DASH classrooms demonstrate improved attitudes toward science, school, self, and others.

Early results from these detailed case studies indicate that teachers who are trained in and use DASH teach more science and teach it more effectively than they did earlier and that they and their students find the program enjoyable and beneficial. Additional studies are being conducted to expand the data base for these claims. Specifically, students in DASH

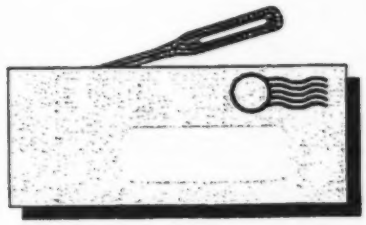
1. Consistently demonstrate a high proportion of engaged learning time.
2. Demonstrate knowledge and understanding of important concepts and skills in science, health, and technology.
3. Integrate and apply important science, health, and technology concepts across content areas.
4. Integrate new science, health, and technology concepts with prior knowledge and experiences.
5. Connect and apply what they learn in school to their lives.
6. Demonstrate proficiency in investigative skills. (Includes questioning, inquiry, library research, measurement, curiosity, and others.)
7. Consistently take and share responsibility for their own learning and classroom operations.
8. Use cooperative learning strategies when appropriate.
9. Demonstrate positive attitudes toward school, science, self, and others.

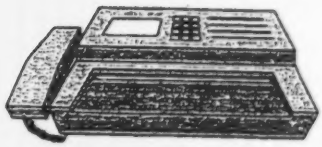
DASH SUPPORT SERVICES

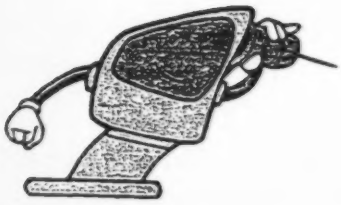
As we have researched and developed the dissemination and implementation model for DASH, we have learned much. We know that for successful implementation, training is essential. The DASH training institutes are designed to make every activity contribute to successful teachering. Those who have experienced the DASH institutes know they are intensive, tiring, effective, and fun. Most teachers leave with a renewed excitement about teaching and are eager to return to the classroom to try out new ideas.

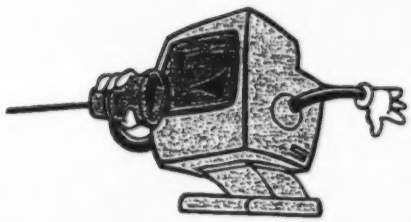
However, we have also learned that institutes alone are not enough for full implementation and long-term maintenance of a program. also needed is follow-up, coaching, and inservice during the first year of implementation. To accomplish full implementation, we require that a local coordinator be identified for each teacher institute. Local coordinators serve as links between DASH teachers and the DASH project. They help make sure that the equipment and supplies are available; that teachers have opportunities to observe one another teach and to meet and discuss successes and problems; that additional inservice is provided if needed, (that communication with the DASH project is continued) and that teachers are encouraged to work through the time when the DASH style of teaching feels awkward or even frustrating.

Over the years, we have developed and tested a variety of highly effective follow-up activities that are now available for implementing DASH. These activities support the efforts of the local coordinators. Many of them are simple and inexpensive. The following table identifies the kinds of follow-up services available to DASH teachers and schools. It briefly describes each service, and then indicates how to request such services. For further information on any of these services, contact the DASH project.









Support Services for CRDG Science Programs

Support service	Description	To request services
Telephone contact & Teleconference Free	Administrative follow-up to see that materials have arrived is provided to all new schools. Inquiries to the CRDG hot line about special problems are answered within 24-48 hours. Voice mail is provided on project phones for after-hour contact and to accommodate differences in time zones. Teleconferences may be requested to accompany a meeting of teachers after they have discussed successes, problems, and issues. Teleconference with project staff at no cost to user.	Project inquiries: Ph: (800) 799-8111 Fax (808) 956-9486 *DASH* (808) 956-6918 *FAST* (808) 956-7863 *HMSS* (808) 956-7863
Direct mail Free	Written responses to inquiries, notices, advisories, suggested parent letters, recognitions, the *Science Education* newsletter and other information are mailed directly to teachers at no cost.	CRDG Dissemination University of Hawaii 1776 University Ave Honolulu, HI 96822
Computer network Connection cost	Direct contact with project staff. Provides opportunities for local coordinators, teachers, and administrators to share information with each other and with project staff. The CRDG web site also has current information on products and services.	Call or e-mail for addresses of project staff crdg@hawaii.edu www2.hawaii.edu/crdg
Higher education partners Costs negotiable	Fourteen institutions of higher education provide services for teachers, including assistance in locating funding for training, research assistance, credit for professional-growth activities including training, advanced degree study, and subject area experts as needed.	Contact project staff for partner nearest you.
Certified trainers Costs negotiable	Each project has a cadre of certified trainers nationwide. These highly qualified, experienced teachers provide continuous support services for their own and neighboring school districts. They may also be available to provide services to other districts on a fee-for-services basis.	Contact project staff.
Implementation Support Program Costs negotiable	A 1-3 year program supporting teachers in classrooms implementing CRDG science programs. Monthly agendas include discussion of successes and problems, presentation of philosophy and pedagogy, activities based on presentations, review of participant-identified topics and activities.	Contact project staff.
Site visitations Costs negotiable	Site visitations build understanding and support for the program. Visits include classroom observations, additional training, problem-solving, assistance with adaptations, and so on.	Contact project staff.
Renewal workshops Costs negotiable	A 1-3 day workshop for teachers who are well advanced in implementation and would like a refresher workshop. Renewal workshops are for teachers who have used a program for three or more years.	Contact project staff.

Concept Mapping in Science

by Carol Ann Brennan

Designers and teachers of the *Developmental Approaches in Science, Health, and Technology* (*DASH*) program for elementary schools have found concept mapping a useful instructional strategy.

This article describes the developmental steps that *DASH* teachers use in teaching concept mapping, the forms the maps take, and the functions of the mapping process in instruction.

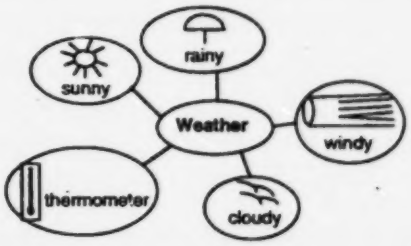


Figure 1. Step 1 DASH concept map on weather.

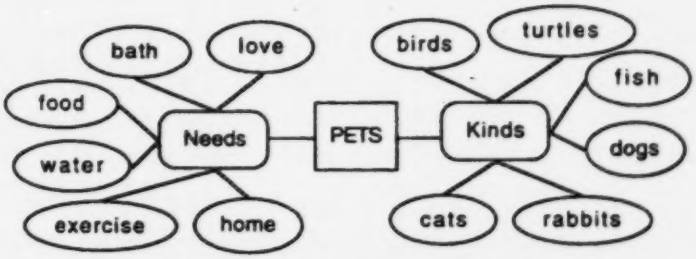


Figure 2. Step 2 DASH concept map showing subcategories.

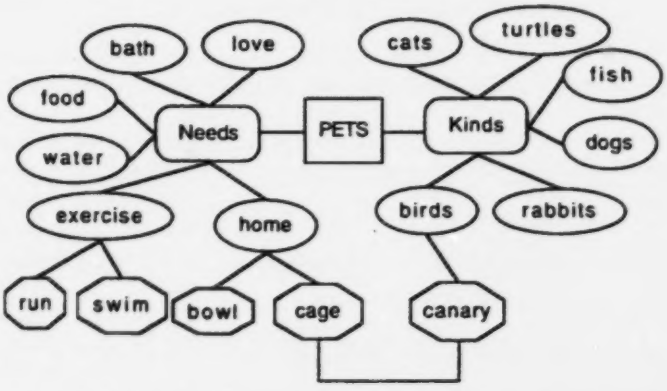


Figure 3. Step 3 DASH concept map on pets, showing a cross-link.

Five Steps in Learning to Construct Concept Maps

DASH Concept Mapping: Step 1. Teachers introducing concept mapping to early learners most often model the process with the whole class—a role important in teaching a new skill (Vygotsky 1978). The teacher usually begins by announcing the topic for the concept map and asking students what they know about it. All ideas are acceptable—correct or incorrect, related or unrelated. This brainstorming session reveals what students think they already know about the topic. In this first step, students' ideas are simply *connected* to the concept name.

The teacher helps students record their ideas. Older students usually use words; kindergartners are more likely to use pictures—drawn by a student or teacher or cut from a magazine. The teacher or a student labels the pictures. Figure 1 shows the first-step version of a *DASH* kindergartners' concept map. As students become proficient in written language, they gradually switch to using words, but pictures are never inappropriate on a *DASH* map. One small picture can often express more than a volume of words.

A teacher may use another medium for creating a concept map, such as having students act out or role-play their ideas. Or students might use physical objects such as leaves, stems, and other plant parts to create their maps. These kinesthetic and physical representations are often recorded in visual or written form.

Concept Mapping: Step 2. Even beginning students move quickly to the next step in learning to map concepts: they begin to categorize their ideas. For example, students constructing a concept map on pets are able to put their ideas into two categories, such as *Kinds of Pets* and *Needs of Pets*. See Figure 2. The teacher may model this second step initially, but students usually begin categorizing spontaneously in response to a question such as *Do some of these ideas seem to go together?* In this step, colors and shapes may indicate levels in a hierarchy of concepts.

Concept Mapping: Step 3. In the third step, students group ideas into three or more levels. This hierarchical ranking of ideas evolves throughout students' mapping experiences. Young children often create uneven categories, incorporating noncoordinate groups at the *same* hierarchical level. They typically use a center-out arrangement rather than the top-down arrangement in step 5 maps.

In the third step, students, even kindergartners, also add lines to show connections between subcategories. For example, one student may have drawn a canary and

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Table 1. Developmental steps in the *DASH* concept-mapping process.			
Step	Form of entries	Hierarchical levels	Links
1	pictures, words, labeled pictures	2 levels; radiating from center	connecting lines
2	same	3 levels; use of shapes and colors for levels	same
3	same	3 or more levels	cross-links between sub-categories
4	same	same	labeled links; arrows on lines
5	mostly words	top-down structure	print and line styles

Table 1 summarizes the five steps in concept mapping in DASH.

put it with *birds* under *Kinds of Pets*. Another student may draw a cage and put it in the *homes* category under *Needs of Pets*. One of these students will likely see a connection between the *cage* and the *canary* or *bird* category. See Figure 3 for an example of a cross-link between categories. As students become proficient in mapping, this cross-linking becomes quite complex. Most early learners peak at step 3 in learning to construct concept maps.

Concept Mapping: Step 4. In step 4, students add labels to show relationships between linked categories and add arrows to the linking lines. Link labels rarely appear on concept maps by kindergartners and first-graders because of their lack of proficiency with written language. But these young students often verbalize the connective words when contributing their ideas.

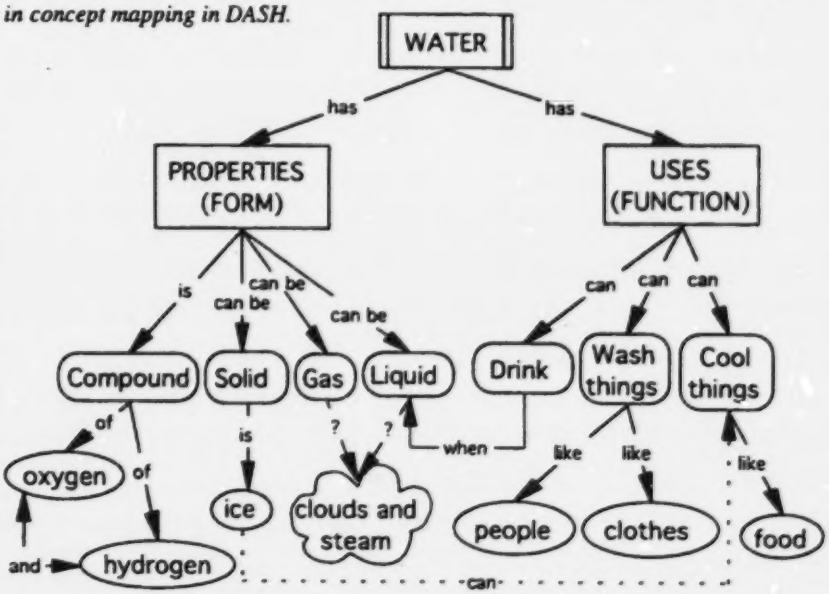

Figure 4. Concept map on water showing DASH steps 4 and 5.

Concept Mapping: Step 5. The fifth step in mapping is using a formal hierarchy. The eventual goal of arranging concepts on a map, according to Novak (1984), is to create a formal hierarchy in which "the more general inclusive concepts should be at the top of the map, with progressively more specific, less inclusive concepts arranged below them." In the *DASH* program, more advanced students are encouraged to use a top-down organization for their maps. These students often use shapes and colors to highlight the hierarchical order. (*DASH* leaves to students or teachers the choice of forms, shapes, colors, and so on.) These students also learn to use directional arrows, words or lines in color, and even different styles of print to show relationships between concepts. Figure 4 shows some advanced techniques and elements used by experienced concept mappers.

Note that as students become more adept at creating concept maps, the teacher's role diminishes. In a kindergarten class, the teacher almost always participates, modeling the process and asking questions to solicit students' ideas, then helping them to categorize and label those ideas. The teacher may suggest ideas or categories to stimulate students to respond. In the primary grades, as students gain experience, the teacher does less modeling, finally becoming a coach or facilitator who occasionally asks a question and assists students who need help. Early learners rarely become so proficient that they can create class maps independently.

DASH Concept Mapping: Forms

Materials and means of construction determine a concept map's form. *Form* here includes not only ways of recording ideas on maps but also ways of showing how maps are constructed and by whom.

DASH teachers and students are urged to be ingenious in devising ways to create concept maps. In an unpublished 1993 master's paper, DeFrank analyzed forms and techniques used in *DASH* for recording ideas and aligned them with the enhancement of learners' multiple intelligences hypothesized by Gardner (1983).

The examples here are similarly arranged. The ideas come from DeFrank and from the author's observations and experiences. Since many concept-mapping forms support more than one of Gardner's set of intelligences, they are bound to overlap. Because the goal here is to suggest just some of the many possibilities, much of the overlap was deleted.

Linguistic forms used in creating concept maps include words, both written and spoken, illustrated by the labels on pictures and the discussion inherent in constructing a group map.

Mathematical-logical forms are exemplified by hierarchical structures and the use of patterns or shapes. One type of hierarchy appearing often on concept maps is a linear arrangement—a type of flowchart—for showing a process, such as steps in planting a seed.

Spatial-visual forms used in concept maps include pictures, symbols, realia, color, and computer programs. The visual arrangement of maps supports this mode of learning. Teachers have suggested using photos or cartoons to represent concepts on a map.

Bodily-kinesthetic forms include role-playing and acting out of ideas. The movable nature (see also the following section on function) of *DASH* concept maps is especially supportive to the kinesthetic learner. In one kind of kinesthetic map, students might *pretend* to be their favorite pets. They begin to create subcategories when all the *same kinds* of pets, such as dogs or cats, form a group and join hands. To encourage further connections for the map, a teacher might next ask each *pet* to move to its preferred *home* or *food*, perhaps represented by pictures drawn earlier by students. The *fish* would likely move to the *aquarium* and join hands with the *turtle*, or the *bunny* might go to the *carrot*, and so on. (This sort of categorizing has been done on a smaller scale on a tabletop or bulletin board with pictures or cutouts. The critical element is the mobility of the ideas or elements and links on the map.)

Musical intelligence as described by Gardner is the ability to produce and appreciate rhythm, pitch, and timbre. This is perhaps the most difficult intelligence to accommodate in concept mapping, but kindergarten and primary teachers are the most likely to invent ways to map concepts *musically*. These teachers might invent songs or rhymes that encourage children to sing their related ideas about kinds of energy. Rhyming aphorisms about kinds of health habits have been particularly successful with these young students.

Intrapersonal and interpersonal forms for concept maps involve *who* is constructing the map—the mapmakers or cartographers. The transition from class maps to individual maps can come as early as kindergarten. But in most *DASH* classes throughout the grades the maps are created as class projects.

The mapping efforts of individual early learners are usually incomplete representations of what children actually know about a topic, just because their attention spans are short and their writing and drawing still primitive. These characteristics do not dictate that they should never construct their own maps, especially if they choose to do so. The teacher just needs to recognize both the limitations and the benefits. Teachers often address individual learners and perhaps the intrapersonal intelligence by having students sign their own names on their pictures or contributions. Having students reflect on their own contributions to the map and their own understanding of the concept is perhaps more in line with Gardner's description of the intrapersonal intelligence.

Concept maps are also created by small groups of students within a class. All groups might construct maps on the same concept, then compare, contrast, and combine them into a class concept map. Or each group may map a subcategory of the main concept. For example, if the concept is *insects*, one group might map *kinds*, another *parts*, a third *life cycles*, a fourth *uses*, and so on. All these *subconcept* maps are reviewed by the other groups, changed as deemed necessary, and then combined into a class map about *insects*. An idea that has succeeded well with young students in *DASH* is to have them work with older, more-experienced students in multi-age small groups to create concept maps.

DASH Concept Mapping: Functions

Functions refers to what a map can do and how it can be used by students and teachers. Many uses of concept maps are detailed in *DASH*, but students and teachers are always encouraged to invent new uses for their maps.

DASH uses concept mapping as an ongoing instructional strategy. A *DASH* concept map is a dynamic, evolving thing rather than a static, one-time event (e.g., Novak & Gowin 1984). Some authors do suggest that several maps can be made during the development of a given concept in an instructional unit or course. These multiple maps are often done in a pre-test/post-test fashion. *DASH*, however, uses the initial concept map, modifying it during the period of instruction on the concept. Once the study ends, the map becomes a reference source during further instruction, and students are always encouraged to make additions, deletions, or changes to any of their concept maps at any time.

In *DASH* the initial class map of a concept ascertains students' prior knowledge. Because all contributions, right or wrong, are accepted, teachers get a picture of both what students know and what misconceptions they have about the concept. The map also sets the stage to reflect the dynamic, changing nature of science. (After all, many early scientific ideas have been overturned. We now know the sun, not the earth, to be the center of the solar system.)

DASH students learn that what they consider correct today may change as they investigate that idea tomorrow. Students are encouraged to raise questions about topics or concepts they may want to explore. In this way the map becomes a useful tool for planning instruction.

As students engage in activities and learn more about a topic or concept, they return to the map periodically, adding ideas, revising information, and even deleting entries. They usually make changes in a different color and date them, making an ongoing picture of the development of their understanding of the topic or concept. At the end of the study, the map reflects what the class has learned and gives the teacher a tool for developing an assessment instrument and a criterion for measuring each student's achievement.

In *DASH*, concept maps are used for purposes other than guiding instruction and assessing achievement. For example, a class can map a process and use the map to assign jobs for a project such as growing a garden.

Small groups may use maps to design or plan a project, to record data, or to present the results of their research. In upper grades, individually made maps are sometimes used instead of a traditional test.

Many teachers use concept maps across subject areas. In language arts, maps can be used in brainstorming ideas for a story and organizing them, much as outlines are used. Concept maps can be vehicles for analyzing stories and books. Some teachers have students use mapping as a way to record notes when reading from a textbook, watching a video, or listening to a lecture. Most of the ideas suggested for science are applicable to social studies. In short, the functionality of concept mapping is limited only by students' and teachers' imaginations.

In summary, uses for concept maps suggested in *DASH* include assessing, planning, organizing, recording, summarizing, brainstorming, and displaying the ongoing development of a concept. What concept maps can provide or do for students and teachers is the topic of a future article.

Concept Mapping in *FAST* and *HMSS*

Although concept mapping was first conceived for use with college students, this article described its applications in elementary *DASH* classes. But it is of course useful in grades beyond K–6—for example, in *FAST* and *HMSS* classes. The developmental steps still apply, but students are more likely to use words than pictures or objects, and they should move through the first three steps quickly. The forms and functions described here are also useful with these older students.

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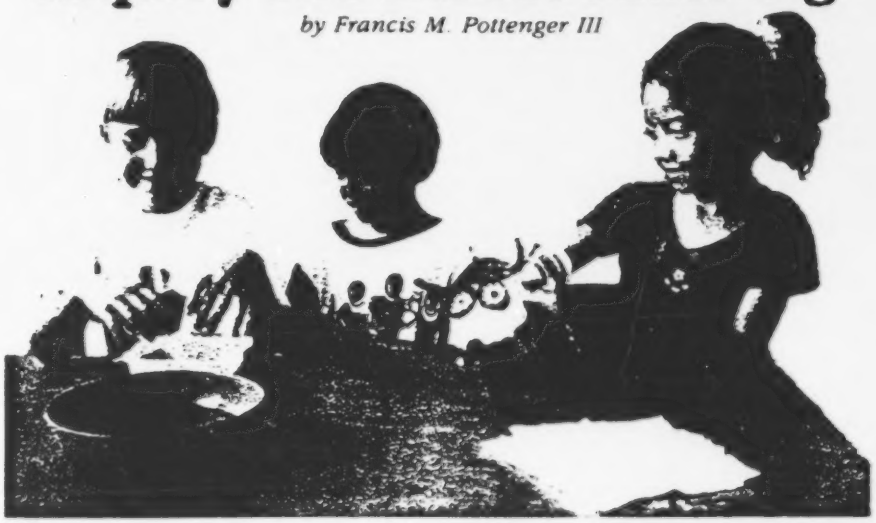
Inquiry and Direct Teaching

by Francis M. Pottenger III



When teachers begin using a new curriculum that marches under the banner of inquiry, some expect to find inquiry as the sole mode of presentation. Instead they often find a mix of modes. Why? Because, for many reasons, students cannot possibly create and find anew all the knowledge our society deems essential for them to know.

Two general kinds of strategies are available for teaching concepts and skills required by society: direct teaching and inquiry teaching. Direct teaching transmits to students what is *known* via the teacher, a book, a video, or other repository of knowledge. In contrast, inquiry teaching instructs students in how to probe things *not known* (or treated as not known) so as to gain understanding of how knowledge has been made and how they themselves can make new knowledge on their own. Inquiry also teaches knowledge through the experience of inquiry itself.

Direct teaching is essential for transmitting conventions of communication and social behavior. It is also used to transmit conceptual, artifactual, and methodological knowledge. Conventions and crafted artifacts are unique inventions whose origins are lost in antiquity. They are the products of arbitrary creative decisions—for example, the words and syntax of language, accepted social behavior, forms of music, and so forth. Re-creation of these knowledge products is not possible, yet they are essential to cultural continuity. Hence they must be taught by techniques that assure precision in transmission, retrieval, and use. Their preservation depends on techniques of direct teaching, which typically use demonstration in some form, after which students internalize and replicate an invention, correcting it until it meets acceptable standards.

Inquiry is essential to finding out about things unknown or not understood. The natural sciences, which seek to make natural phenomena understandable, have been built with the methods of inquiry. Engineering, agriculture, medicine, and other technologies use these methods in testing the utility of invented devices, techniques, and systems. In parallel

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Weird Science

by Mike Baiocchi

I was just strolling through, so to speak, my educational experience when I was broadsided by a most peculiar class. The first day I spent in freshman science was a bit awkward. There were no books. There was a lesson plan, but no lecture. This disturbed me. Until this freshman course, I had spent little time dwelling on science. I would do the necessary listening and memorizing, get my "A," and go home. All the while I was fooling myself into believing I was understanding new things, understanding in new ways, that which was around me.

I was taught the terms "density," "precipitation," and "heat," but I never owned the ideas that made these words. I could, on the day I walked into freshman science, tell you that "density" was "mass divided by volume," but comprehending what I meant when I said that was beyond me. My head was filled with ideas that were not my own. I had not participated in forming or realizing the concepts. I had no sovereign right to claim ownership of the ideas. I was a peon, far from the sovereign kings of these thoughts. "Density" was not vital to anything I did, so I learned its definition and moved on. In this freshman science class I was not allowed the luxury of moving on. I was asked "why?" so many times and in so many ways that I wanted to scream. The term "to grok" from Robert Heinlein's book *Stranger in a Strange Land* means to "understand completely, to understand to such a point that the idea is owned." For the first time in my education I was asked to do more than retain a word and someone else's idea. I was being asked to "own" it.

It was as if I had shattered the mirror, and moved beyond. No longer was I reflecting back information that was poured into me. I was finally engaged in discovering, for myself, the "why" of things. I moved to the front line of learning. Instead of absorbing others' ideas, I was recreating and ultimately "grokking" those terms I "learned" so long ago. I was amazed at my ability to take ideas apart and put them back together again. It was like peeling away layers of haze. The obscured abstract that had been my goal all along was now out of its package, shiny and new. Previously, I had never dared to change the equations I learned. Now I was finding that I could rearrange the ideas, my ideas, in new ways to make my way through the dark.

After learning that things could be learned in a truer way, I felt a need to re-examine the whole of my education. Had I spent all these years learning useless facts? Had I been distracted by the package all these years? I thought about what I felt I needed to know and how well I felt I needed to know those things. I concluded that only through meshing both styles of learning could I hope for the best education. To truly understand the idea takes considerable effort and a long, cumbersome process. Reinventing, in intimate detail, the knowledge of several thousand years of civilization is neither efficient nor practical, but every once in a while a jarring is necessary. A test, such as freshman science, is needed to prove just how firm your understanding really is. There are connections to be made between ideas that only a sovereign understanding can afford.

Editor's Note: Mike Baiocchi is a former student of Steve Bartasius, a FAST I *teacher from Gray-New Gloucester High School in Gray, Maine. Steve sent us this essay, written for a senior Honors English class, to share Mike's insightful reflections on his freshman* FAST *experience. Thank you both. Well done!*

Inquiry and Direct Teaching, continued from page 1

fashion to the teacher's role in direct teaching, nature serves as a scientist's teacher, providing demonstrations of phenomena and then correction of ideas formulated about those phenomena. But rather than simply internalizing and accepting nature's demonstration, scientists and students alike must process the experience of the demonstration by observing, testing, and interpreting.

A closer look at inquiry illuminates this observing, testing, and interpreting cycle. There are at least two general types of inquiry: discovery and experiment. Discovery happens when we find something new. The observation may be accidental—looking up and discovering the moon during the day, for example. Or it may be intentional—such as looking for bones in a tar pit. Once made, a discovery becomes a prototype for further discovery and a part for assemblage into larger wholes.

Experimentation entails testing. In its several forms, it can range from satisfying simple curiosity (for example, testing to see what will happen if I take that rock from under that wheel) to testing of an explanatory hypothesis (for example, growing grass under bushes with and without leaf mold to test the hypothesis that less grass grows under bushes than in an open meadow because bush leaf mold kills the grass). Discovery and experiment are often joined processes occurring sequentially or concurrently.

While the arbitrary character of social conventions requires direct teaching plus a teacher's corrections to assure fidelity in transmitting knowledge, nature is an even more rigorous overseer, correcting inquiry by the very regularities that inquiry seeks to understand. Since nature always points inquiry in the same direction, it can be re-experienced endlessly. However, the immensity of the body of knowledge compiled by the natural sciences, along with the difficulty of experiencing many phenomena (they occur on the ocean bottom or in distant space) limits the use of inquiry in teaching natural science in schools. There is only enough time and direct accessibility to phenomena for students to get the flavor of recapitulated science and associated technology. Hence the information base and the theory structure of much of science must be taught directly, just as it must be communicated through the journals of the sciences.

Precious then are the few things selected for students to know through discovery and experimentation, for what is selected carries the double burden of exciting students' imagination while teaching inquiry processes. Our CRDG programs emphasize inquiry in the early years to keep curiosity alive and to unfold the most fundamental ideas of the sciences. We have found that, once students know how the grounding ideas of a science are created, they can construct usable personal knowledge structures from direct teaching of evolved concepts and theory. For these reasons, inquiry and direct teaching are companions in CRDG's programs from the early grades upward.

Food from ARF to the Pyramid

by Francis M. Pottenger III and Carol Ann Brennan

Coming up with a food-grouping system that young children can understand and use is a challenge. Young *DASH* students seem to grasp the World Health Organization's scheme of three food groups linked to major functions in the human body: *activation*, *regulation*, and *fabrication*. These ideas are introduced in kindergarten. Grade 1 students learn about the ARF Food Group System through song, rhyme, and aphorism. (See Figure 1.) In grade 2, students learn the basic components of foods: fats, carbohydrates, proteins, and vitamins and minerals. In grade 3, they learn about the recommended number and size of servings.

In the ARF system, *A* stands for foods that *activate* the body, giving it energy to make it go. These include complex carbohydrates, fats, and sugar. Complex carbohydrates come from starches such as breads, cereals, rice, and pasta. *R* stands for foods (including vitamins and minerals) that help *regulate* how the body works. *F* stands for foods, mainly proteins, used to *fabricate*, or build and repair the body. Figure 2 shows the ARF Food Group System on a wheel.

Because few foods consist of only one component, the diagram shows that foods may be *simple*, containing mostly one component, or *compound*, containing large amounts of two or more components. For example, a compound food containing simple activation and regulation foods (ACT/REG) could be a fruit pie or a lettuce-and-tomato sandwich. Figure 2 shows this refinement, along with the recommended number of servings.

In the ARF diagram in Figure 2, you can use color to highlight the combining of *simple* foods to produce *compound* foods. One way is to color activation foods *yellow*, regulation foods *blue*, and fabrication foods *red*. Next color the activation and regulation (ACT/REG) section *green*, the compound regulation and fabrication section (REG/FAB) *purple*, and the fabrication and activation section (FAB/ACT) *orange*. Color the all-inclusive foods in the center (ACT/FAB/REG) *brown*.

The ARF Food Group Song

Activation, activation,
Makes me move, groove and move.
Potatoes, rice, and shredded wheat,
Butter, bread, and candy sweet,
Activation foods,
Activation foods.

Regulation, regulation,
Makes me work, perk and work.
Spinach, corn, and cauliflower,
Apples, raisins, fiber power,
Regulation foods,
Regulation foods.

Fabrication, fabrication,
Makes me grow, repair and grow.
Beans, chops, and turkey legs,
Milk, fish, steak, and eggs,
Fabrication foods,
Fabrication foods.

(Sing to the tune of *Are You Sleeping.*)

The ARF Food Group Rhyme

Grains and butter, a sourdough roll,
Potato and sugar, cereal in a bowl.
These are foods for activation.
For crawling and climbing, getting all hot,
For running and jumping, turning on a dot.
Making bodies move is activation.

Spinach and cauliflower, corn on the cob,
Apples and oranges, pureed peaches in a glob.
These are foods for regulation.
For digesting and defending, controlling things inside,
For seeing and thinking, directing what's supplied.
Making bodies work is regulation.

Steak and beans, roasted chicken legs,
Milk and codfish, ham served with eggs.
These are foods of fabrication.
For building and maintaining, making muscles strong,
For repairing and growing, making bone that's long.
Making bodies grow is fabrication.

ARF Aphorisms

Eat the group of three
In wide variety.

When selecting foods in the right amounts,
Remember the ARF serving counts.
We need at least 6 servings of A and 5 of R,
And 4 of F to be up to par.

Figure 1. ARF Food Group Song, Rhyme, and Aphorism

In grade 4, *DASH* introduces the Food Pyramid put out by the United States Department of Agriculture. (See Figure 3.) With it comes the conceptual problem of rationalizing two disparate systems. This problem is resolved when youngsters see that the Fabrication foods include both the dairy and the meat, fish, and poultry groups of the Pyramid. The Regulation group contains both the fruit and vegetable groups of the Pyramid, and the Activation group contains the Pyramid's carbohydrate group and its fat and sugar groups. To help in this recognition, *DASH* shows the Pyramid's groups as subcomponents in the ARF diagram.

Using the coloring scheme of the ARF wheel on the Pyramid (Figure 3) can show the similarities in these two systems. On the Pyramid, color the top row (fats) and the bottom row (complex carbohydrates) *yellow*. Color the milk and meat row *red*, and color the fruit and vegetable row *blue*. The colors add a visual representation to the verbal one.

Both the ARF system and the Food Pyramid show the recommended number of servings of each kind of food by the area they occupy. In summary, the Food Pyramid shows the *quantity* and *form* or kinds of food. The ARF system shows *function* along with *quantity* and *form*, and it accounts for *simple* and *compound* foods. Students need to be familiar with the Food Pyramid because it appears on cereal boxes and other prepared foods they use at home. We encourage you to help your students to learn about and use both systems.

Figures 2 & 3 on page 76.

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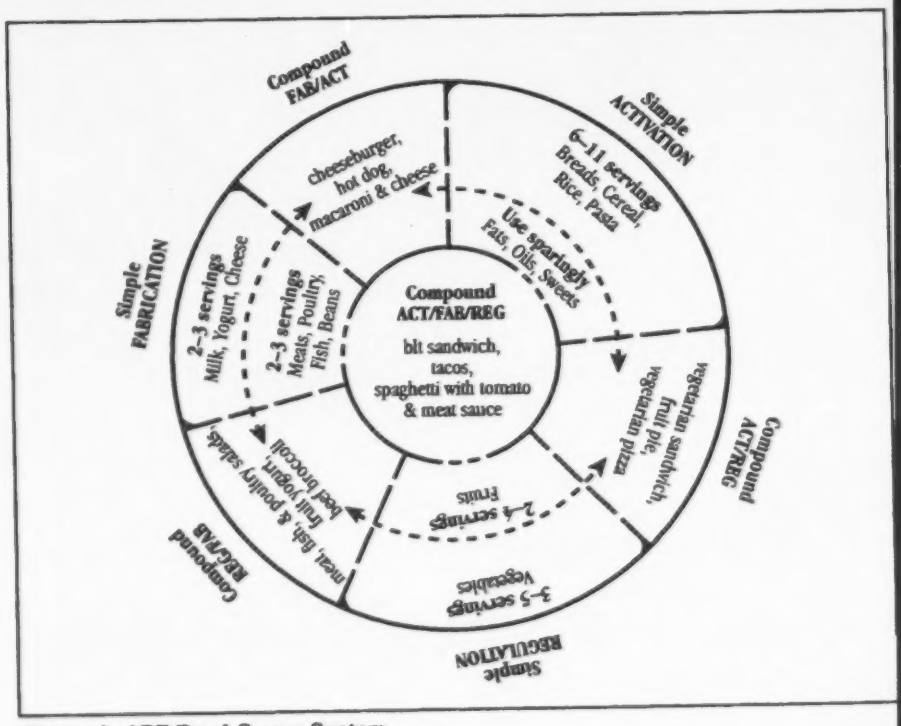
Compound FAB/ACT
cheeseburger, hot dog, macaroni & cheese
Simple ACTIVATION
6–11 servings Breads, Cereal, Rice, Pasta
Use sparingly Fats, Oils, Sweets
Simple FABRICATION
2–3 servings Milk, Yogurt, Cheese
2–3 servings Meats, Poultry, Fish, Beans
Compound ACT/FAB/REG
blt sandwich, tacos, spaghetti with tomato & meat sauce
Vegetarian sandwich, fruit pie, vegetarian pizza
Compound ACT/REG
2–4 servings Fruits
meat, fish, & poultry salads, fruit yogurt, beef broccoli
Compound REG/FAB
3–5 servings Vegetables
Simple REGULATION

Figure 2. ARF Food Group System

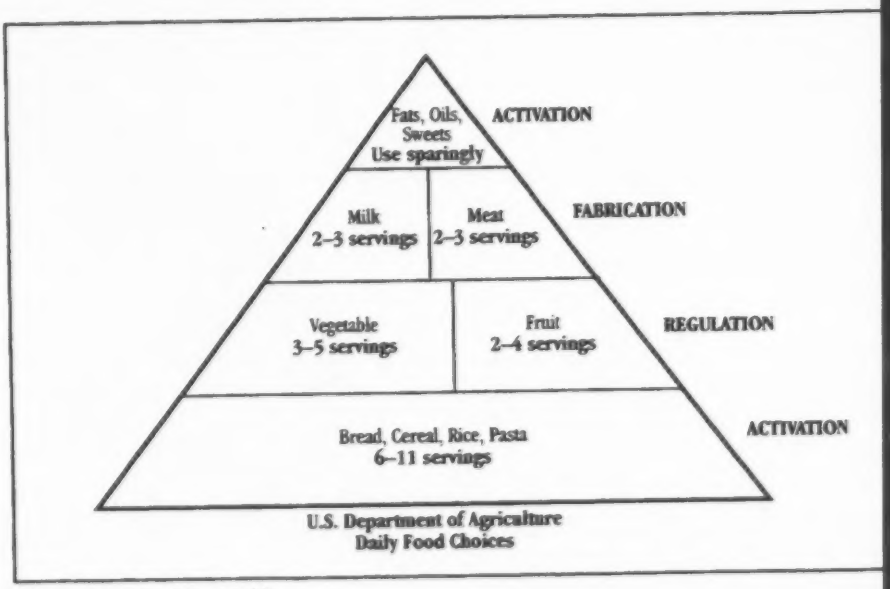

Figure 3. Food Pyramid

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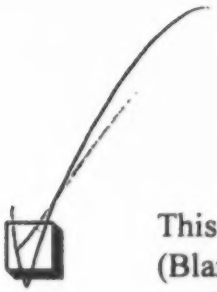

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